UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF WASHINGTON
AT SEATTLE

MALIKIE INNOVATIONS LTD. and
KEY PATENT INNOVATIONS LTD.,

Plaintiffs,

v.

NINTENDO CO. LTD. and
NINTENDO OF AMERICA, INC.,

Defendants.

Case No. _____

COMPLAINT FOR PATENT INFRINGEMENT

JURY TRIAL DEMANDED

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Plaintiffs Malikie Innovations Limited ("Malikie") and Key Patent Innovations Limited ("KPI") (collectively, "Plaintiffs"), by and through their undersigned counsel, bring this Complaint for patent infringement and damages against Defendants Nintendo Co. Ltd. and Nintendo of America, Inc. (collectively, "Nintendo" or "Defendants") and, in support, allege the following:

THE PARTIES

1. Plaintiff Malikie is the successor-in-interest to a substantial patent portfolio created and procured over many years by Blackberry Ltd., formerly known as Research in Motion Ltd., and its predecessor, subsidiary, and affiliate companies (collectively, "Blackberry"). Malikie is an Irish entity duly organized and existing under the laws of Ireland. Malikie has registered offices at The Glasshouses GH2, 92 Georges Street Lower, Dun Laoghaire, Dublin A96 VR66, Ireland.

2. Plaintiff KPI is the beneficiary of a trust pursuant to which Malikie owns, holds, and asserts the Asserted Patents. KPI is an Irish entity duly organized and existing under the laws of Ireland. KPI has registered offices at The Glasshouses GH2, 92 Georges Street Lower, Dun Laoghaire, Dublin A96 VR66, Ireland.

3. On information and belief, Defendant Nintendo Co., Ltd. is a Japanese company with a regular place of business at 1101 Kamitoba hokotate-cho, Minami-ku, Kyoto 601-8501 Japan.

4. On information and belief, Defendant Nintendo of America, Inc. is a Washington corporation, with its principal place of business at 4600 150th Avenue NE, Redmond, Washington 98052, and has a registered agent for service of process Christopher Ward, located at 4600 150th Avenue NE, Redmond, Washington 98052.

5. On information and belief, Defendants have made, imported, sold, offered for sale, used, induced or contributed to others' use of the Accused Products, and continue to do so, in the United States, the State of Washington, and in the Western District of Washington.

6. On information and belief, Defendants Nintendo Co., Ltd. and Nintendo of America, Inc. and their employees or officers direct and/or control the actions of their direct and indirect subsidiaries. On information and belief, Nintendo and/or its employees or officers direct

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and/or control the actions of these entities by, for example, inducing and contributing to the actions complained of herein. Defendants and their affiliates are part of the same corporate structure and distribution chain for making, importing, offering to sell, selling, and/or using the Accused Products in the United States, including in the State of Washington generally and in this judicial District in particular.

7. Defendants and their affiliates regularly contract with customers regarding products made for or on behalf of those customers.

8. Defendants and their affiliates operate as a unitary business venture and are jointly and severally liable for the acts of patent infringement alleged herein.

JURISDICTION

9. Plaintiffs incorporate by reference paragraphs 1-8 herein.

10. This is an action arising under the patent laws of the United States, 35 U.S.C. § 1 *et seq.*, including without limitation 35 U.S.C. §§ 271, 281, 283, 284, and 285. Accordingly, this Court has subject matter jurisdiction pursuant to, *inter alia*, 28 U.S.C. §§ 1331, 1332, and 1338(a).

11. This Court has general and specific personal jurisdiction over Nintendo, due at least to its continuous presence in, and systematic contact with, this judicial district. Nintendo is registered to do business in the State of Washington, and its headquarters is in this District. Nintendo is subject to this Court's jurisdiction pursuant to due process at least as a result of Nintendo's substantial business in Washington and this judicial District, including at least part of its infringing activities, the regular conductance of and soliciting of business at and from its local facilities, and engaging in persistent conduct and deriving substantial revenue from goods and services provided in and from the State of Washington, including in this District.

12. This Court further has general and specific jurisdiction over Nintendo because Nintendo, directly or through subsidiaries or intermediaries, including distributors, retailers, franchisees, and others, has committed and continues to commit acts of infringement in this judicial District, giving rise to this action by, among other things, making, using, offering for sale, and/or selling products, services, and systems that infringe the Asserted Patents.

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13. Plaintiffs' causes of action arise, at least in part, from Defendants' contacts with and activities in and/or directed to this District and the State of Washington.

VENUE

14. Plaintiffs incorporate by reference paragraphs 1-13 herein.

15. Venue is proper in this judicial District pursuant to 28 U.S.C. §§ 1391(b), (c), (d), and 1400(b) because Nintendo has a permanent and continuous presence in, has committed acts of infringement in, and maintains regular and established places of business in this District. In addition, a substantial part of the acts or omissions giving rise to Malikie's claims occurred in this District.

16. Defendants are doing business, either directly or through respective agents, subsidiaries, or intermediaries, on an ongoing basis in this Judicial District and elsewhere in the United States and have committed acts of infringement in this District.

17. On information and belief, Defendants make, use, sell, offer to sell, and/or import infringing products into and/or within this District, maintain a permanent and/or continuing presence within this District, and have the requisite minimum contacts with this District such that this venue is a fair and reasonable one.

18. Upon information and belief, Defendants have transacted and, at the time of filing of the Complaint, are continuing to transact business within this District.

19. Venue is further proper in this District over Defendant Nintendo Co., Ltd. because it is a foreign corporation. Venue is also proper as to a foreign defendant in any district. 28 U.S.C. § 1391(c)(3); *In re HTC Corp.*, 889 F.3d 1349 (Fed. Cir. 2018). Defendant Nintendo Co., Ltd. is a foreign corporation organized under the laws of Japan, with a principal place of business in Japan.

PATENTS-IN-SUIT

20. Malikie is the assignee of and owns all right and title to U.S. Patent Nos. 8,545,247 ("the '247 Patent"); 8,115,731 ("the '731 Patent"); 9,542,571 ("the '571 Patent"); 8,610,397 ("the '397 Patent"); 7,529,305 ("the '305 Patent"); and 9,313,065 ("the '065 Patent") (collectively, the

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"Asserted Patents").

21. The Asserted Patents were developed by inventors working for Blackberry and its predecessors. Blackberry developed numerous innovative and diverse technologies, including groundbreaking inventions pertaining to the use, display, and control of data on, as well as the use, display, control, and charging of portable electronic devices.

22. The '571 Patent, titled "System and Method of Owner Application Control of Electronic Devices," was duly and lawfully issued on January 10, 2017. A true and correct copy of the '571 Patent is attached hereto as Exhibit A.

23. The '731 Patent, titled "Method of Operating a Handheld Device for Directional Input," was duly and lawfully issued on February 14, 2012. A true and correct copy of the '731 Patent is attached hereto as Exhibit B.

24. The '397 Patent, titled "Battery Charger for Portable Devices and Related Methods" was duly and lawfully issued on December 17, 2013. A true and correct copy of the '397 Patent is attached hereto as Exhibit C.

25. The '247 Patent, titled "Dock for Portable Electronic Device," was duly and lawfully issued on October 1, 2013. A true and correct copy of the '247 Patent is attached hereto as Exhibit D.

26. The '305 Patent, titled "Combination of Space-time Coding and Spatial Multiplexing, and the use of Orthogonal Transformation in Space-time Coding" was duly and lawfully issued on May 5, 2009. A true and correct copy of the '305 Patent is attached hereto as Exhibit E.

27. The '065 Patent, titled "Scattered Pilot Pattern and Channel Estimation Method for MIMO-OFDM Systems" was duly and lawfully issued on April 12, 2016. A true and correct copy of the '065 Patent is attached hereto as Exhibit F.

28. Blackberry, as the previous owner of the Asserted Patents, contacted Nintendo and its representatives on or about December 3, 2020 to notify Nintendo of its infringement of numerous patents.

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29. Blackberry, as the predecessor-in-interest of the Asserted Patents, offered Nintendo the chance to license any of its patents.

30. On December 3, 2020, BlackBerry sent each of the Defendants a letter offering to license any or all of its patents, including the Asserted Patents, to Nintendo. The letter noted that BlackBerry believed Nintendo infringed at least the '731 Patent, the '397 Patent, the '305 Patent, and the '065 Patent, among others.

31. Having received no responses to its earlier letters, on January 28, 2021, Blackberry again sent each of the Defendants a letter offering to license any or all of its patents, including the Asserted Patents, to Nintendo.

32. Nintendo did not take a license under any Blackberry patent, including the Asserted Patents, from Blackberry.

33. After its acquisition of the Blackberry patents, Malikie also offered Nintendo a license under any or all of its patents, including the Asserted Patents.

34. On August 14, 2023, Malikie sent Nintendo a letter identifying 19 Malikie patents infringed by Nintendo products and services. The patents identified by Malikie as infringed by Nintendo included the '731 Patent, the '397 Patent, the '305 Patent, and the '065 Patent, among others.

35. In December 2023, representatives for Malikie met with representatives for Nintendo in Redmond, Washington to engage in patent license discussions concerning the Malikie patents, including the Asserted Patents.

36. After months of making no progress in those license discussions, on August 9, 2024, Malikie sent another letter to Nintendo identifying additional patents infringed by Nintendo, including the '247 Patent and the '571 Patent, among others, and offering to license its 802.11 and Wi-Fi Alliance standards-essential patents ("Wi-Fi SEPs") to Nintendo at specified per unit rates.

37. As of the filing of this Complaint, Nintendo has not agreed to take a license under any Malikie patent, including the Asserted Patents, nor provided either confirmation of its

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willingness to take a license under any Wi-Fi SEP at the rates offered by Malikie, or a counter-offer with a rate it would be willing to pay for such a license.

ALLEGATIONS OF PATENT INFRINGEMENT

COUNT I
INFRINGEMENT OF U.S. PATENT NO. 9,542,571

38. Malikie re-alleges and incorporates herein by reference paragraphs 1-37 of its Complaint.

39. The ’571 Patent is generally directed to systems and methods of owner application control of electronic devices.

40. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under the doctrine of equivalents one or more claims, including without limitation at least claim 10 of the ’571 Patent, having made, used, tested, sold, leased, licensed, offered for sale, and/or imported the Nintendo Parental Controls App. *See* Exhibit G.

41. Defendants also indirectly infringed the ’571 Patent under 35 U.S.C. § 271(b) and (c).

42. Defendants knowingly, intentionally, and actively aided, abetted, and induced others to directly infringe at least claim 10 of the ’571 Patent by, for example, having sold, offered for sale, and encouraged customers to use electronic devices with the infringing Nintendo Parental Controls App. Defendants, for example, provided instructions on how to access and use the Parental Control App on the Nintendo Switch Device, as shown in the citations provided in Exhibit G. *See also https://www.nintendo.com/us/switch/parental-controls/?srsltid=AfmBOooePJLUOQcVUA0Ld5ileeGBZbuM1i06v_yPbiRU9fZsvU02Si9w.* Defendants continued to so instruct and encourage customers and users of the Nintendo Switch and Parental Controls App even after they were specifically put on notice of the ’571 Patent including the reasons for their infringement.

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43. Defendants contributed to the direct infringement of at least claim 10 of the '571 Patent under 35 U.S.C. § 271(c) by, for example, having supplied, with knowledge of the '571 Patent, a material part of a claimed invention, where the material part was not a staple article of commerce and was incapable of substantial non-infringing use. For example, Defendants provided, owned, operated, sold, offered to sell, leased, and/or imported infringing Nintendo Switch Devices incorporating the Nintendo Parental Controls App and distributed copies of the Nintendo Parental Controls App that were not a staple article of commerce and were incapable of substantial infringing use. Defendants continued their actions even after they were specifically put on notice of the '571 Patent, including the role that the Nintendo Parental Controls App played in Defendants' infringement.

44. Defendants' infringement was willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others.

COUNT II
INFRINGEMENT OF U.S. PATENT NO. 8,115,731

45. Malikie re-alleges and incorporates herein by reference paragraphs 1-44 of its Complaint.

46. The '731 Patent is generally directed to operating a handheld device for directional input.

47. Defendants have been on notice of the '731 Patent and have had a specific factual basis for their infringement of the '731 Patent since at least December 3, 2020, as well as through the course of letters correspondence and discussions with BlackBerry and Malikie and the filing of this Complaint.

48. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under the doctrine of equivalents, and continue to directly infringe, one or more claims, including without limitation at least claim 1 of the '731 Patent, by making, using, testing, selling, leasing,

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licensing, offering for sale, and/or importing the Nintendo Switch with Joy-Con Controllers, Nintendo Switch OLED with Joy-Con Controllers, and Nintendo Switch Lite with built-in controllers. *See* Exhibit H.

49. Defendants also indirectly infringe the '731 Patent under 35 U.S.C. § 271(b) and (c).

50. Defendants knowingly, intentionally, and actively aid, abet, and induce others to directly infringe at least claim 1 of the '731 Patent by, for example, selling, offering for sale, and encouraging customers to use infringing Nintendo Switch with Joy-Con Controllers, Nintendo Switch OLED with Joy-Con Controllers, and Nintendo Switch Lite with built-in controllers. Defendants advertise and explain to customers and users how the Joy-Con Controllers and built-in controllers function with the Nintendo Switch devices, including how physical movement with the controllers can be tracked using the accelerometer and gyroscope and processed by the processor to cause the graphical elements on the Switch to visually move according to the displacement and movement of the Joy-Con Controllers or built-in controllers. This is shown, for example, in the evidence shown in Exhibit H. *See also https://www.youtube.com/watch?v=DKBK4OnvjX0&list=PL2JiZAV5BmDXx6qFj76MFxgLxEQetsWzII.* Defendants continued to so instruct and encourage customers and users even after they were specifically put on notice of the '731 Patent including the reasons for their infringement.

51. Defendants contribute to the direct infringement of at least claim 1 of the '731 Patent under 35 U.S.C. § 271(c) by, for example, supplying, with knowledge of the '731 Patent, a material part of a claimed invention, where the material part is not a staple article of commerce and is incapable of substantial non-infringing use. For example, Defendants provide, own, operate, sell, offer to sell, lease, and/or import infringing Joy-Con Controllers that are not a staple article of commerce and are incapable of substantial infringing use (for example, with any other gaming console or without utilizing the claimed features). Defendants continued their actions even after they were specifically put on notice of the '731 Patent, including the role that the Joy-Con Controllers play in Defendants' infringement.

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52. Defendants' infringement is willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others.

COUNT III
INFRINGEMENT OF U.S. PATENT NO. 8,610,397

53. Malikie re-alleges and incorporates herein by reference paragraphs 1-52 of its Complaint.

54. The '397 Patent is generally directed to battery charging for portable devices.

55. Defendants have been on notice of the '397 Patent and have had knowledge of a specific factual basis for their infringement of the '397 Patent since at least December 3, 2020, as well as through the course of letters correspondence and discussions with BlackBerry and Malikie and the filing of this Complaint.

56. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under the doctrine of equivalents, one or more claims, including without limitation at least claim 1 of the '397 Patent, by making, using, testing, selling, leasing, licensing, offering for sale, and/or importing the Nintendo Switch with Dock. *See* Exhibit I

57. Defendants also indirectly infringed the '397 Patent under 35 U.S.C. § 271(b) and (c).

58. Defendants knowingly, intentionally, and actively aided, abetted, and induced others to directly infringe at least claim 1 of the '397 Patent under 35 U.S.C. § 271(b) by, for example, having sold, offered for sale, and encouraged customers to use the Nintendo Switch with the infringing accompanying Nintendo Switch Dock and/or the infringing accompanying Nintendo Switch AC Adapter, each with a USB Type-C connector; the infringing Nintendo Joy-Con Charging Grip with the accompanying USB Type-C cable connected to the infringing Nintendo Switch Dock and/or the infringing Nintendo Switch AC Adapter, and the Nintendo Switch Pro Controller with the accompanying USB Type-C cable connected to the infringing Nintendo Switch

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Dock and/or the infringing Nintendo Switch AC Adapter. Defendants instructed customers and users how to charge the devices using the USB connection, which infringes the '397 patent. *See https://www.nintendo.com/my/support/qa/detail/33826?srsltid=AfmBOooLwnE_08e8OM_uGeQfnUJsKCzjPtnG0jtAYra13eNUlCSUfEhz*. Defendants continued to so instruct and encourage customers and users even after they were specifically put on notice of the '397 Patent including the reasons for their infringement.

59. Defendants contributed to the direct infringement of at least claim 1 of the '397 Patent under 35 U.S.C. § 271(c) by, for example, having supplied, with knowledge of the '397 Patent, a material part of a claimed invention (such as the Nintendo Switch Dock or a replacement Nintendo Switch Dock, the Nintendo Switch AC Adapter or replacement Nintendo Switch AC Adapter, the Nintendo Joy-Con Charging Grip, or other accompanying USB C-type charging cables), where the material part was not a staple article of commerce and was incapable of substantial non-infringing use. For example, Defendants provided, owned, operated, sold, offered to sell, leased, and/or imported infringing Nintendo Switches with Docks and AC Adapters, Nintendo Joy-Con Charging Grips and accompanying USB C-Type charging cables, and Nintendo Switch Pro Controller and accompanying USB C-Type charging cables that were not a staple article of commerce and were incapable of substantial non-infringing use. Defendants continued their actions even after they were specifically put on notice of the '397 Patent, including the role that the Nintendo Switch Dock, Nintendo Switch AC Adapters, the Nintendo Joy-Con Charging Grip, and the USB type-C charging cables accompanying the Nintendo Switch, Nintendo Joy-Con Charging Grips and/or the Nintendo Switch Pro Controller played in Defendants' infringement.

60. Defendants' infringement was willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others.

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COUNT IV
INFRINGEMENT OF U.S. PATENT NO. 8,545,247

61. Malikie re-alleges and incorporates herein by reference paragraphs 1-60 of its Complaint.

62. The ’247 Patent is generally directed to docks for portable electronic devices.

63. Defendants have been on notice of the ’247 Patent and have had a specific factual basis for their infringement of the ’247 Patent since at least August 9, 2024, as well as through the course of letters correspondence and discussions with BlackBerry and Malikie and the filing of this Complaint.

64. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under the doctrine of equivalents, and continue to directly infringe, one or more claims, including without limitation at least claim 1 of the ’247 Patent, by making, using, testing, selling, leasing, licensing, offering for sale, and/or importing the Nintendo Switch Dock. *See* Exhibit J.

65. Defendants’ infringement is willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others.

COUNT V
INFRINGEMENT OF U.S. PATENT NO. 7,529,305

66. Malikie re-alleges and incorporates herein by reference paragraphs 1-65 of its Complaint.

67. The ’305 Patent is generally directed to wireless transmission of space-time coded data streams via multiple antennas in an electronic device.

68. Defendants have been on notice of the ’305 Patent and have had a specific factual basis for their infringement of the ’305 Patent since at least December 3, 2020, as well as through the course of letters correspondence and discussions with BlackBerry and Malikie and the filing of this Complaint.

69. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under

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the doctrine of equivalents, one or more claims, including without limitation at least claim 1 of the '305 Patent, by making, using, testing, selling, leasing, licensing, offering for sale, and/or importing the Nintendo Switch, Switch Lite, and/or Switch OLED. *See* Exhibit K.

70. Defendants also indirectly infringed the '305 Patent under 35 U.S.C. § 271(b) and (c).

71. Defendants knowingly, intentionally, and actively aided, abetted, and induced others to directly infringe at least claim 1 of the '305 Patent by, for example, having sold, offered for sale, and encouraged customers to use infringing the Nintendo Switch, Switch Lite, and/or Switch OLED. Defendants, for example, instructed customers and users how to activate wireless connection on the Switch devices, which infringed the '305 patent, as shown in the citations provided in Exhibit K. *See also https://www.nintendo.com/eu/media/downloads/support_1/nintendoswitch/NSwitch_ImportantInformation_UKV_01.pdf.* Defendants so instructed and encouraged customers and users even after they were specifically put on notice of the '305 patent, including the reasons for their infringement.

72. Defendants contributed to the direct infringement of at least claim 1 of the '305 Patent under 35 U.S.C. § 271(c) by, for example, having supplied, with knowledge of the '305 Patent, a material part of a claimed invention, where the material part was not a staple article of commerce and was incapable of substantial non-infringing use. For example, Defendants provided, owned, operated, sold, offered to sell, leased, and/or imported infringing wireless connectivity in Nintendo Switch, Switch Lite, and/or Switch OLED devices that were not a staple article of commerce and were incapable of substantial infringing use. Defendants continued their actions even after they were specifically put on notice of the '305 Patent, including the role that providing wireless connectivity played in Defendants' infringement.

73. Defendants' infringement was willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others

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COUNT VI
INFRINGEMENT OF U.S. PATENT NO. 9,313,065

74. Malikie re-alleges and incorporates herein by reference paragraphs 1-73 of its Complaint.

75. The ’065 Patent is generally directed to wireless transmission of pilot symbols using orthogonal frequency division multiplexing frames via multiple antennas in an electronic device.

76. Defendants have been on notice of the ’065 Patent and have had a specific factual basis for their infringement of the ’065 Patent since at least December 3, 2020, as well as through the course of letters correspondence and discussions with BlackBerry and Malikie and the filing of this Complaint.

77. Defendants have, under 35 U.S.C. § 271(a), directly infringed, literally and/or under the doctrine of equivalents, one or more claims, including without limitation at least claim 1 of the ’065 Patent, by making, using, testing, selling, leasing, licensing, offering for sale, and/or importing the Nintendo Switch, Switch Lite, and/or Switch OLED. *See* Exhibit L.

78. Defendants also indirectly infringed the ’065 Patent under 35 U.S.C. § 271(b) and (c).

79. Defendants knowingly, intentionally, and actively aided, abetted, and induced others to directly infringe at least claim 1 of the ’065 Patent by, for example, having sold, offered for sale, and encouraged customers to use the infringing Nintendo Switch, Switch Lite, and/or Switch OLED. Defendants, for example, instructed customers and users how to activate wireless connection on the Switch devices, which when the devices utilized WiFi, infringed the ’065 Patent, as shown in Exhibit L. *See also https://www.nintendo.com/eu/media/downloads/support_1/nintendoswitch/NSwitch_ImportantInformation_UKV_01.pdf.* Defendants continued to so instruct and encourage customers and users even after they were specifically put on notice of the ’065 Patent, including the reasons for their infringement.

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80. Defendants contributed to the direct infringement of at least claims 1-8 of the '065 Patent under 35 U.S.C. § 271(c) by, for example, having supplied, with knowledge of the '065 Patent, a material part of a claimed invention, where the material part was not a staple article of commerce and was incapable of substantial non-infringing use. For example, Defendants provided, owned, operated, sold, offered to sell, leased, and/or imported infringing wireless connectivity in Nintendo Switch, Switch Lite, and/or Switch OLED devices that were not a staple article of commerce and were incapable of substantial infringing use. Defendants continued their actions even after they were specifically put on notice of the '065 Patent, including the role that providing wireless connectivity plays in Defendants' infringement.

81. Defendants' infringement is willful in view of the above, and their failure to take any action, even after being put on notice, to stop their infringement or inducement of, or contribution to, infringement by others

PRAYER FOR RELIEF

WHEREFORE, Malikie prays for judgment against Nintendo as follow:

A. That Nintendo has infringed each of the Asserted Patents and, unless enjoined, will continue to infringe one or more of the Asserted Patents;

B. That Nintendo's infringement of one or more of the Asserted Patents has been willful;

C. That Nintendo pay Malikie damages adequate to compensate Malikie for Nintendo's past infringement of each of the Asserted Patents, and present and future infringement of the '731 and '247 Patents, together with interest and costs under 35 U.S.C. § 284;

D. That Nintendo pay pre-judgment and post-judgment interest on the damages assessed;

E. That Nintendo pay Malikie enhanced damages pursuant to 35 U.S.C. § 284;

F. That Nintendo be enjoined from infringing the '731 and '247 Patents or, if its infringement is not enjoined, that Nintendo be ordered to pay ongoing royalties to Malikie for any post-judgment infringement of these patents;

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G. That this is an exceptional case under 35 U.S.C. § 285, and that Nintendo pay Malikie's attorneys' fees and costs in this action; and

H. That Malikie be awarded such other and further relief, including equitable relief, as this Court deems just and proper.

DEMAND FOR JURY TRIAL

Pursuant to Federal Rule of Civil Procedure 38(b), Malikie hereby demands a trial by jury on all issues triable to a jury.

DATED: September 17, 2024

BRESKIN JOHNSON & TOWNSEND, PLLC

s/ *Roger M. Townsend*

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EXHIBIT A

US009542571B2

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

(10) **Patent No.: US 9,542,571 B2**
(45) **Date of Patent: Jan. 10, 2017**

(54) **SYSTEM AND METHOD OF OWNER APPLICATION CONTROL OF ELECTRONIC DEVICES**

(71) Applicant: **BlackBerry Limited**, Waterloo (CA)

(72) Inventors: **Neil P. Adams**, Kitchener (CA); **Michael G. Kirkup**, Waterloo (CA); **Herbert A. Little**, Waterloo (CA); **Russell N. Owen**, Waterloo (CA)

(73) Assignee: **BlackBerry Limited**, Waterloo, Ontario (CA)

(*) 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.: **14/715,227**

(22) Filed: **May 18, 2015**

(65) **Prior Publication Data**

US 2015/0254472 A1 Sep. 10, 2015

Related U.S. Application Data

(63) Continuation of application No. 13/618,311, filed on Sep. 14, 2012, now Pat. No. 9,033,216, which is a (Continued)

(51) **Int. Cl.**
G06F 9/45 (2006.01)
G06F 21/62 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06F 21/6218*** (2013.01); ***G06F 8/61*** (2013.01); ***G06F 12/1458*** (2013.01);
(Continued)

(58) **Field of Classification Search**
USPC 235/375, 380; 719/328; 717/168, 174
See application file for complete search history.

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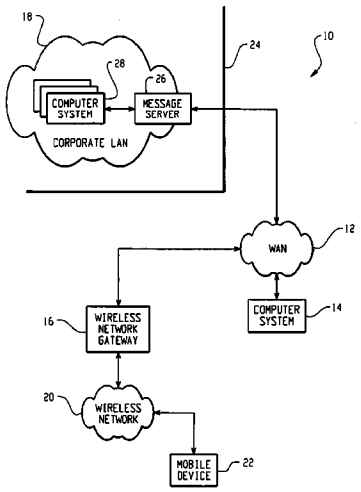
(57) **ABSTRACT**

Systems and methods of owner application control of an electronic device are provided. Owner application control information is stored on the electronic device and/or one or more remote servers. Owner application control information is consulted to determine if one or more required applications are available for execution on the electronic device. If not, one or more required applications not available are downloaded and installed. This could be in a manner transparent to the user of the electronic device. If one or more required applications are not available on the electronic device, the device can be functionally disabled in whole, or in part, until one or more required applications are available.

20 Claims, 9 Drawing Sheets



Related U.S. Application Data

continuation of application No. 12/885,281, filed on Sep. 17, 2010, now Pat. No. 8,887,988, which is a continuation of application No. 11/118,844, filed on Apr. 29, 2005, now Pat. No. 7,815,100, application No. 14/715,227, which is a continuation-in-part of application No. 13/606,814, filed on Sep. 7, 2012, now abandoned, which is a continuation of application No. 12/869,589, filed on Aug. 26, 2010, now Pat. No. 8,302,185, which is a continuation of application No. 10/732,132, filed on Dec. 10, 2003, now Pat. No. 7,793,355.

(60) Provisional application No. 60/567,163, filed on Apr. 30, 2004, provisional application No. 60/432,610, filed on Dec. 12, 2002.

(51) **Int. Cl.**

G06F 12/14	(2006.01)
G06F 21/51	(2013.01)
G06F 21/52	(2013.01)
G06F 21/53	(2013.01)
G06F 21/71	(2013.01)
H04M 1/725	(2006.01)
H04L 29/08	(2006.01)
G06F 9/445	(2006.01)
H04L 29/06	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 21/51*** (2013.01); ***G06F 21/52*** (2013.01); ***G06F 21/53*** (2013.01); ***G06F 21/629*** (2013.01); ***G06F 21/71*** (2013.01); ***H04L 67/34*** (2013.01); ***H04M 1/72525*** (2013.01); *G06F 2221/2149* (2013.01); *H04L 63/102* (2013.01)

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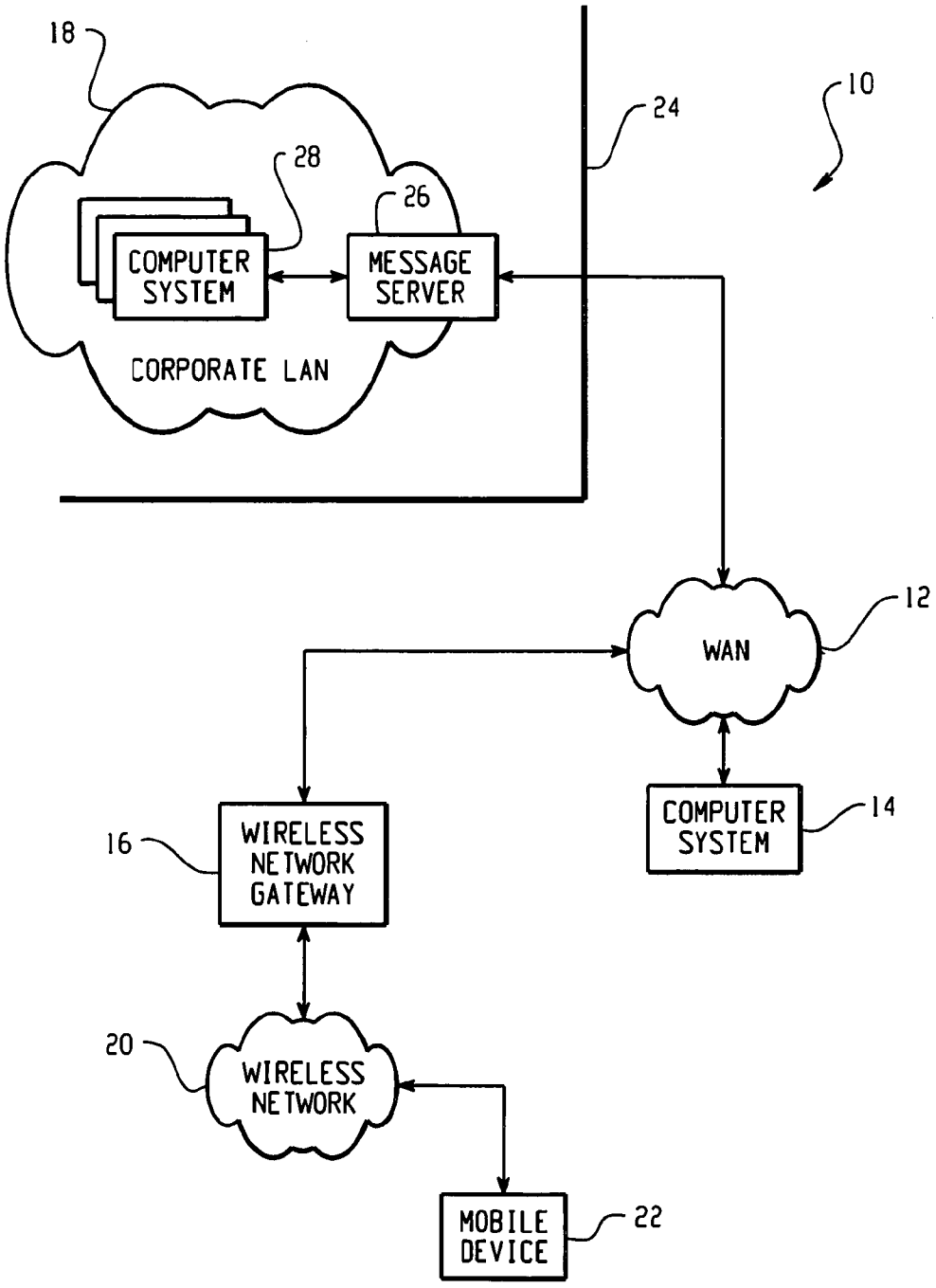
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10
24
28
26
COMPUTER SYSTEM
MESSAGE SERVER
CORPORATE LAN
12
WAN
16
WIRELESS NETWORK GATEWAY
COMPUTER SYSTEM
14
20
WIRELESS NETWORK
MOBILE DEVICE
22

Fig. 1

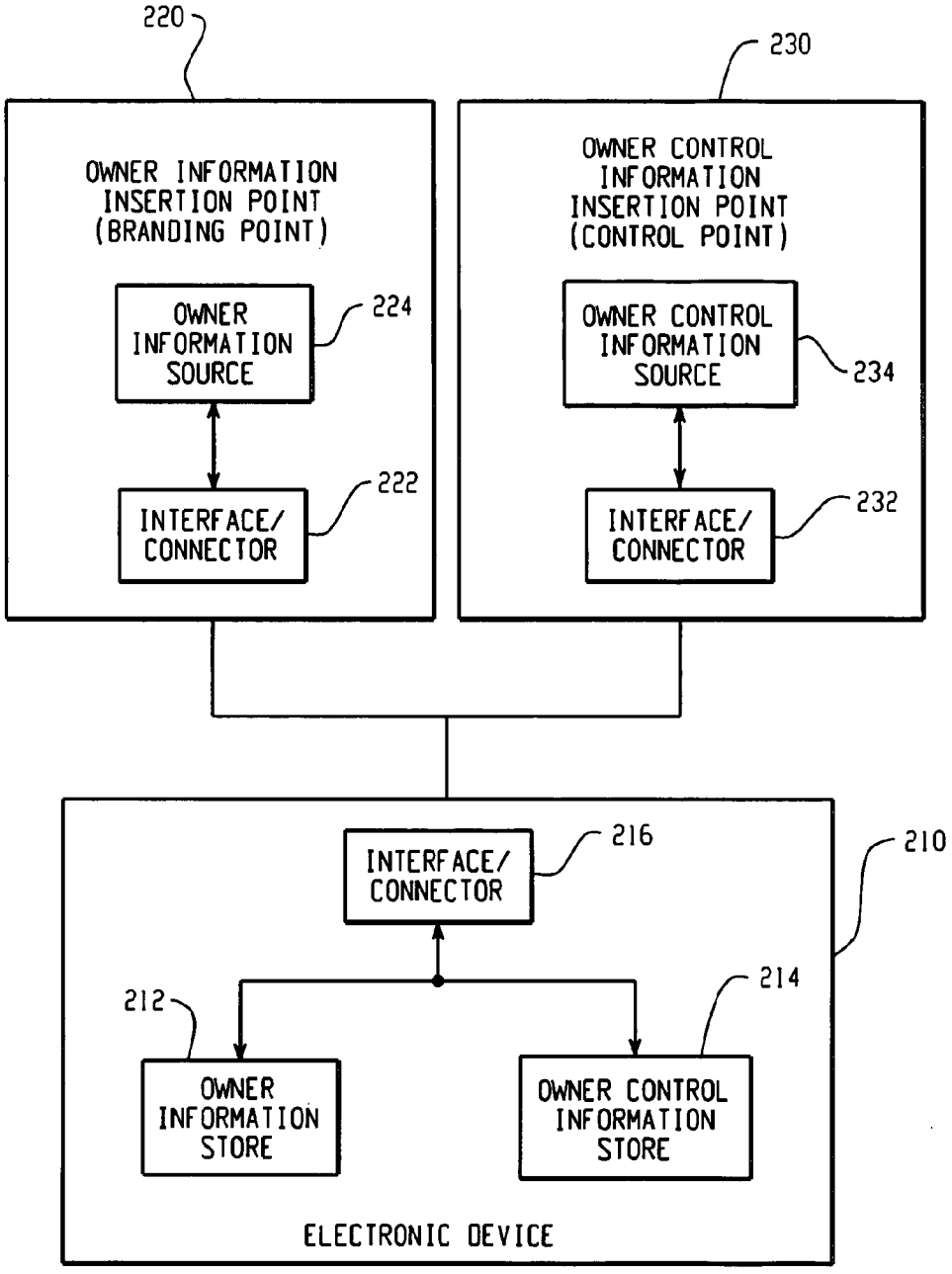

220
230
OWNER INFORMATION INSERTION POINT (BRANDING POINT)
OWNER INFORMATION SOURCE
224
INTERFACE/ CONNECTOR
222
OWNER CONTROL INFORMATION INSERTION POINT (CONTROL POINT)
OWNER CONTROL INFORMATION SOURCE
234
INTERFACE/ CONNECTOR
232
INTERFACE/ CONNECTOR
216
210
212
214
OWNER INFORMATION STORE
OWNER CONTROL INFORMATION STORE
ELECTRONIC DEVICE

Fig. 2

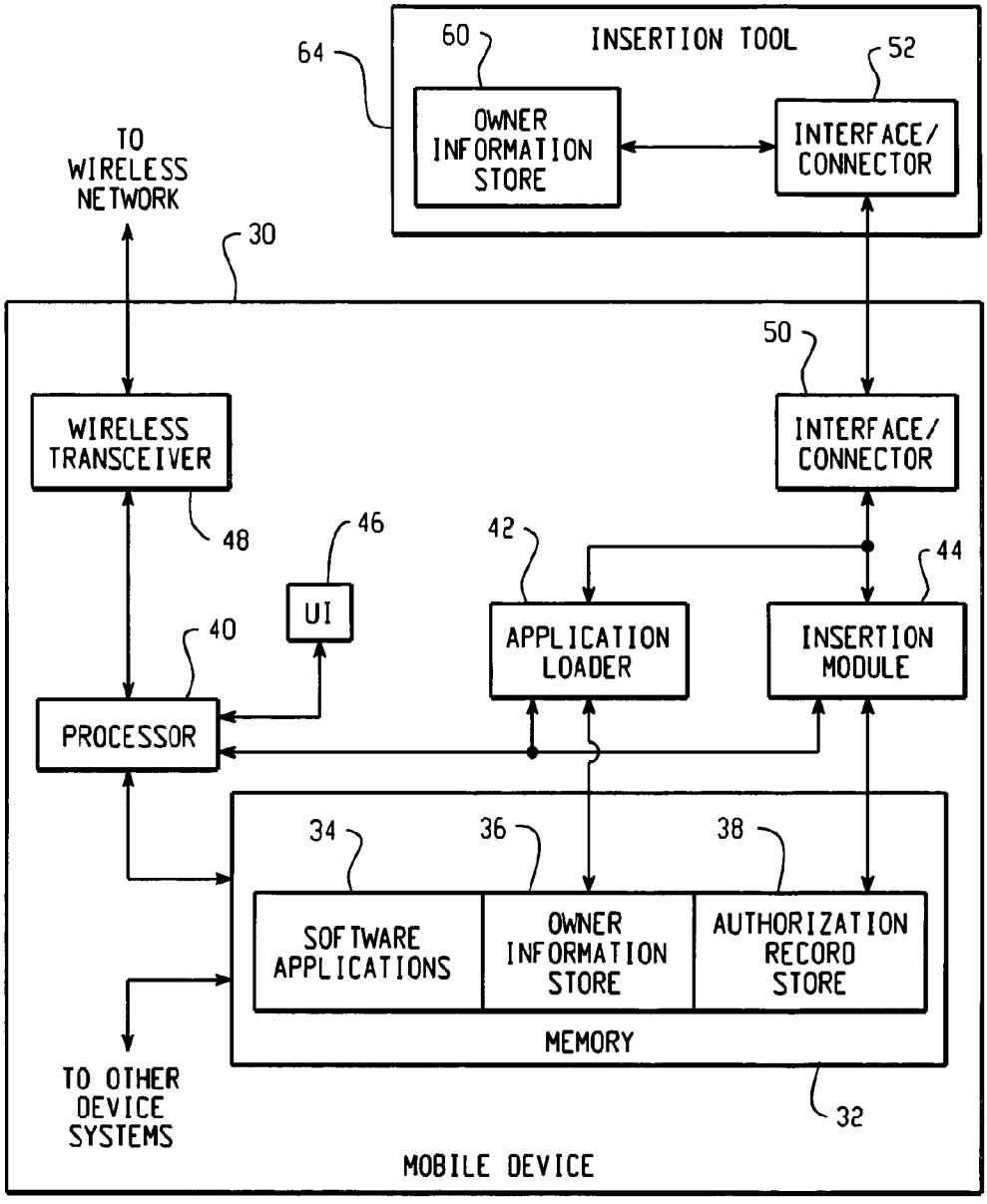

INSERTION TOOL
60
64
52
OWNER INFORMATION STORE
INTERFACE/ CONNECTOR
TO WIRELESS NETWORK
30
50
WIRELESS TRANSCEIVER
INTERFACE/ CONNECTOR
48
46
42
44
UI
APPLICATION LOADER
INSERTION MODULE
40
PROCESSOR
34
36
38
SOFTWARE APPLICATIONS
OWNER INFORMATION STORE
AUTHORIZATION RECORD STORE
MEMORY
TO OTHER DEVICE SYSTEMS
32
MOBILE DEVICE

Fig. 3

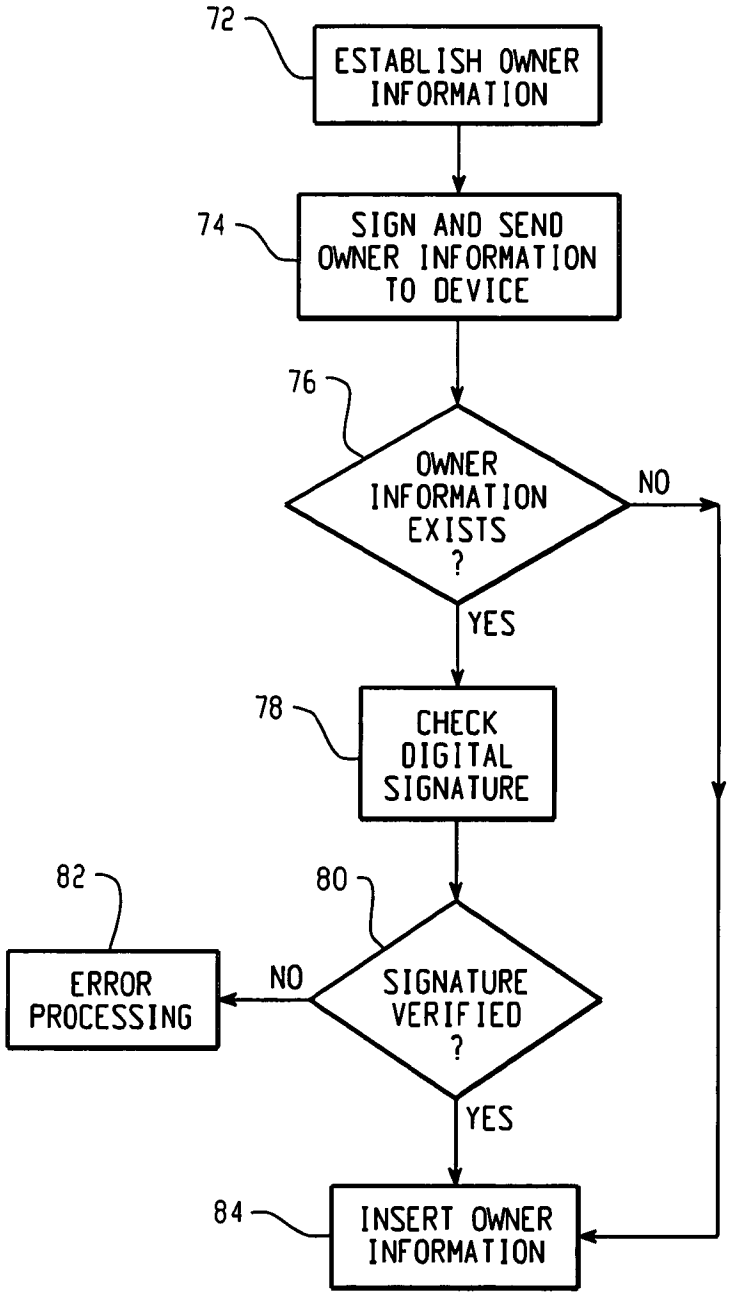

72
ESTABLISH OWNER INFORMATION
74
SIGN AND SEND OWNER INFORMATION TO DEVICE
76
OWNER INFORMATION EXISTS ?
NO
YES
78
CHECK DIGITAL SIGNATURE
82
80
ERROR PROCESSING
NO
SIGNATURE VERIFIED ?
YES
84
INSERT OWNER INFORMATION

Fig. 4

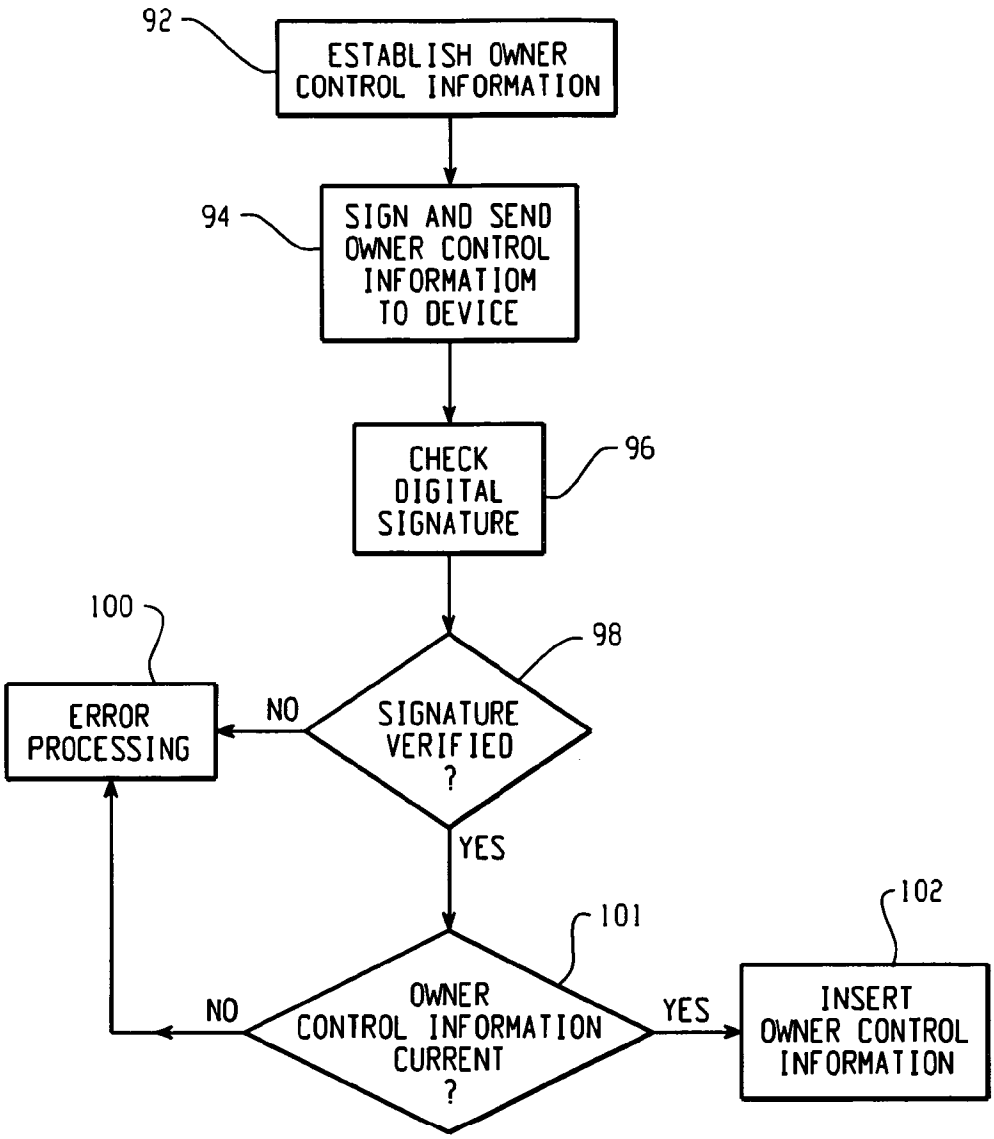

92
ESTABLISH OWNER CONTROL INFORMATION
94
SIGN AND SEND OWNER CONTROL INFORMATIOM TO DEVICE
CHECK DIGITAL SIGNATURE
96
100
98
ERROR PROCESSING
NO
SIGNATURE VERIFIED ?
YES
101
102
NO
OWNER CONTROL INFORMATION CURRENT ?
YES
INSERT OWNER CONTROL INFORMATION

Fig. 5

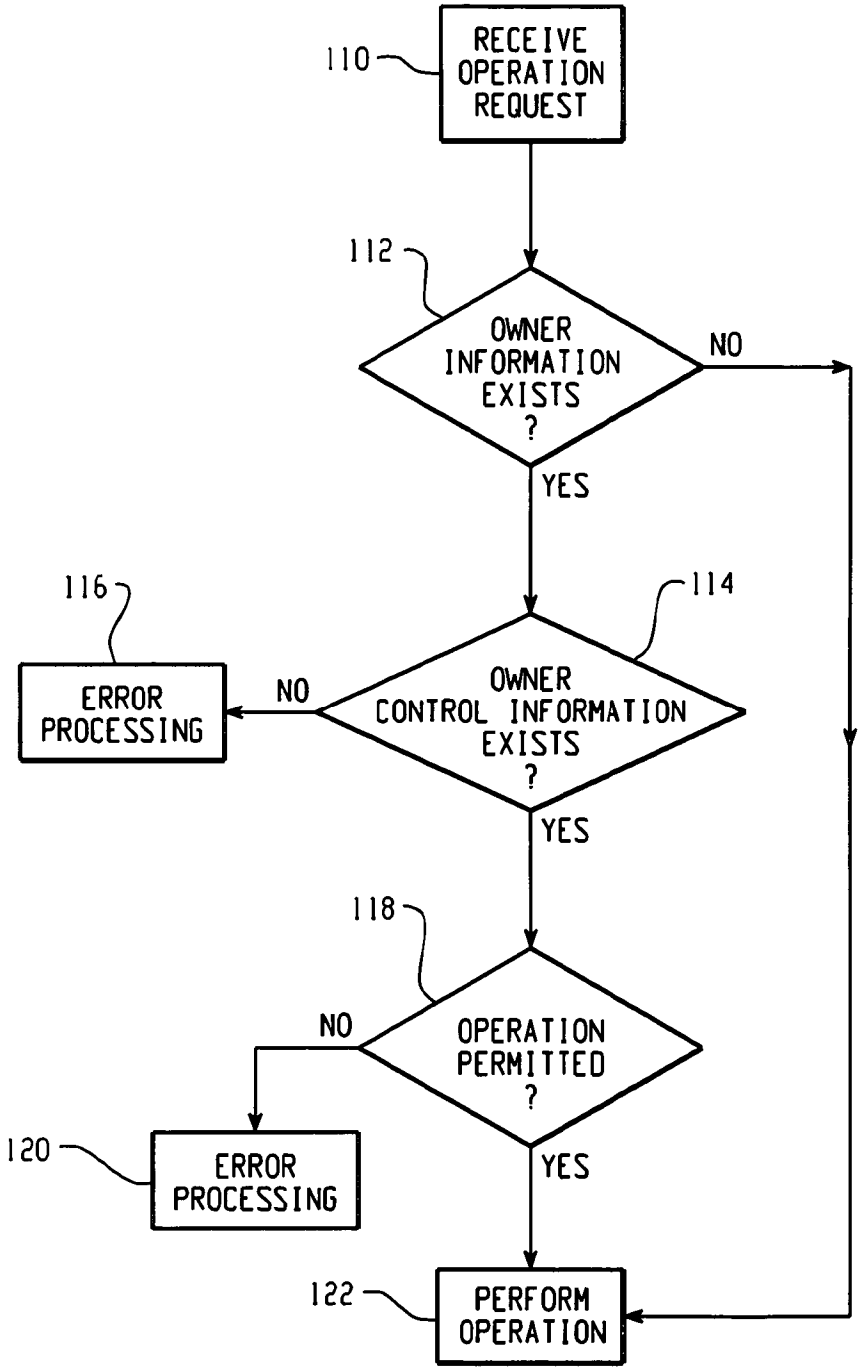
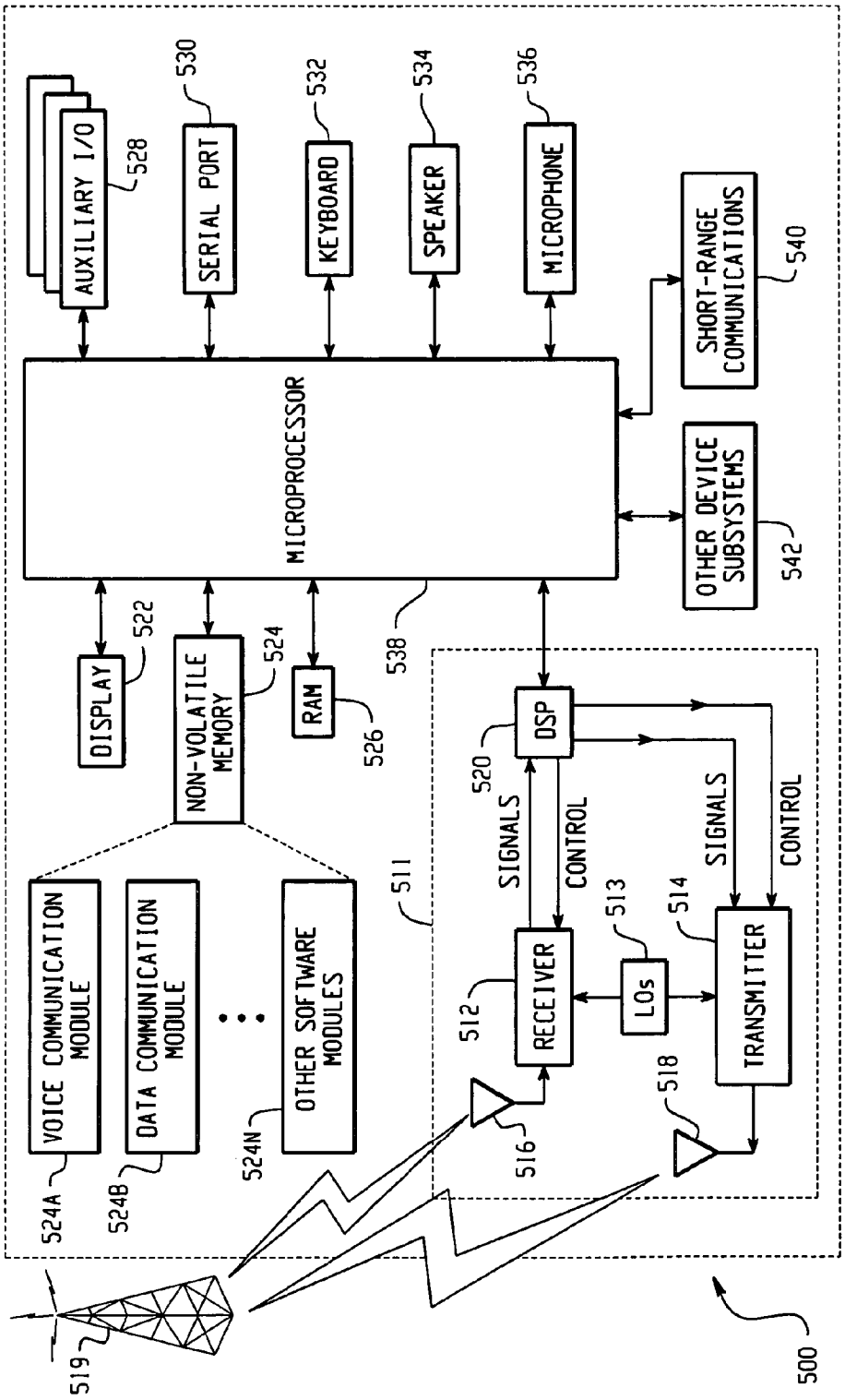

110
RECEIVE OPERATION REQUEST
112
OWNER INFORMATION EXISTS ?
NO
YES
116
ERROR PROCESSING
NO
114
OWNER CONTROL INFORMATION EXISTS ?
YES
118
NO
OPERATION PERMITTED ?
120
ERROR PROCESSING
YES
122
PERFORM OPERATION

Fig. 6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SERIAL PORT
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KEYBOARD
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SPEAKER
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MICROPHONE
536
SHORT-RANGE COMMUNICATIONS
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MICROPROCESSOR
OTHER DEVICE SUBSYSTEMS
542
DISPLAY
522
NON-VOLATILE MEMORY
524
RAM
526
538
DSP
520
SIGNALS
CONTROL
SIGNALS
CONTROL
511
513
514
VOICE COMMUNICATION MODULE
DATA COMMUNICATION MODULE
OTHER SOFTWARE MODULES
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524B
524N
512
RECEIVER
LOs
TRANSMITTER
516
518
519
500

Fig. 7

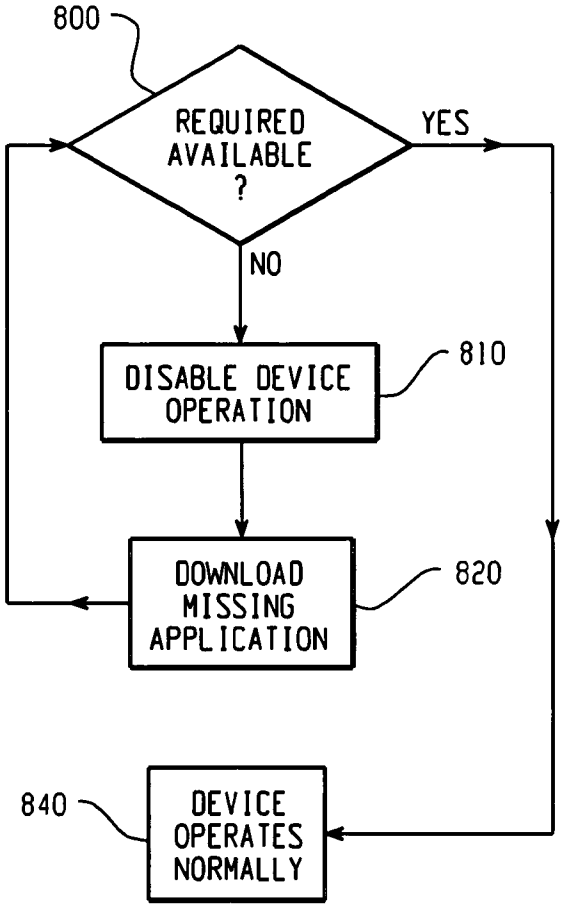
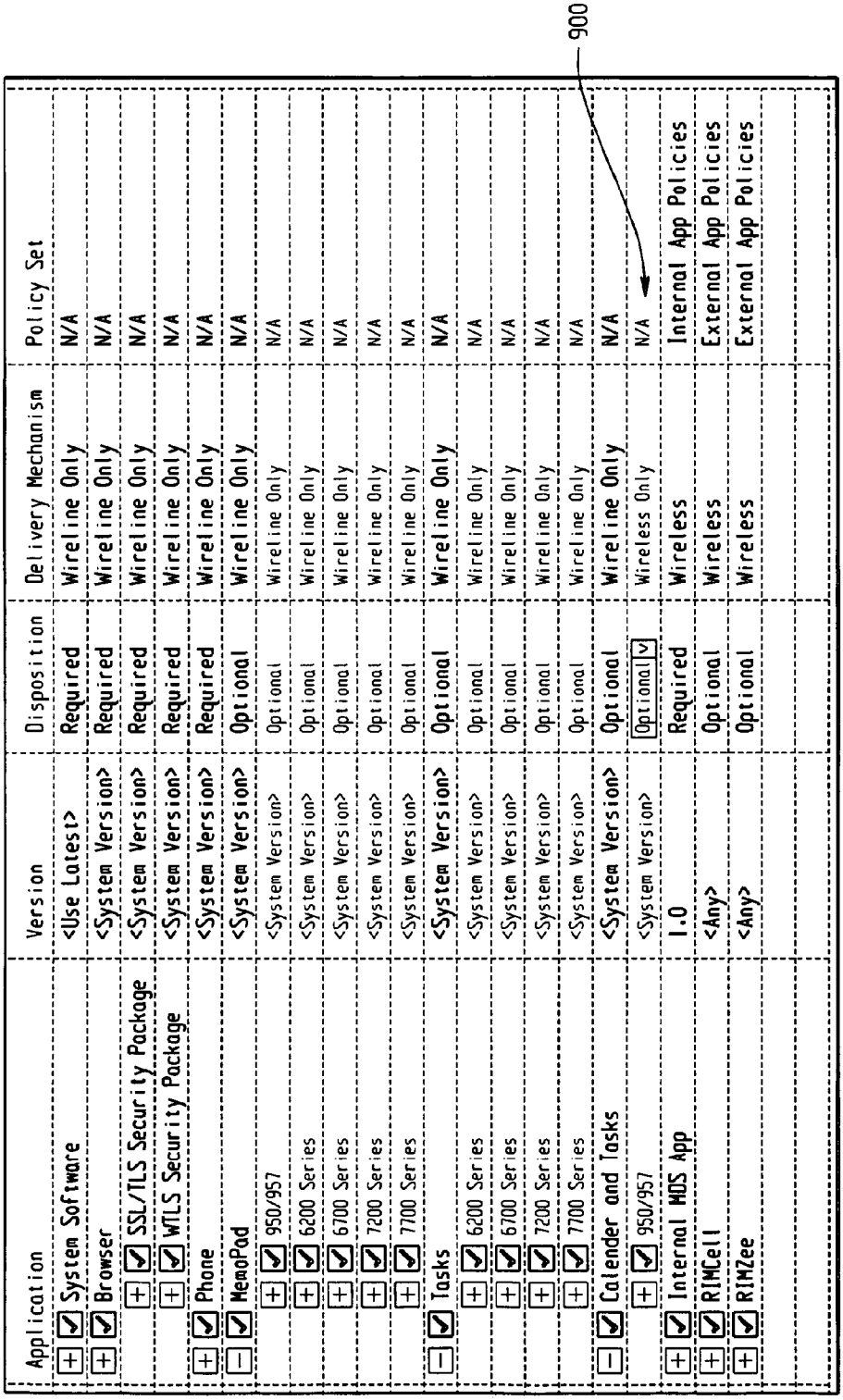

800
REQUIRED AVAILABLE ?
YES
NO
DISABLE DEVICE OPERATION
810
DOWNLOAD MISSING APPLICATION
820
840
DEVICE OPERATES NORMALLY

Fig. 8


900
Application
Version
Disposition
Delivery Mechanism
Policy Set
System Software
<Use Latest>
Required
Wireline Only
N/A
Browser
<System Version>
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Wireline Only
N/A
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N/A
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Calender and Tasks
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N/A
Internal MDS App
1.0
Required
Wireless
Internal App Policies
RIMCell
<Any>
Optional
Wireless
External App Policies
RIMZee
<Any>
Optional
Wireless
External App Policies

Fig. 9

SYSTEM AND METHOD OF OWNER APPLICATION CONTROL OF ELECTRONIC DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/618,311 filed Sep. 14, 2012 by Neil P. Adams, et al. entitled "System and Method of Owner Application Control of Electronic Devices" (11913-US-CNT[2]-4214-25713), which is a continuation of U.S. Pat. No. 8,887,988 issued on Nov. 18, 2014 entitled "System and Method of Owner Application Control of Electronic Devices" (11913-US-CNT-4214-25712), which is a continuation of U.S. Pat. No. 7,815,100 issued on Oct. 19, 2010 entitled "System and Method of Owner Application Control of Electronic Devices" (11913-US-PAT-4214-25701), which claims priority to and the benefit of U.S. Provisional Application No. 60/567,163 filed Apr. 30, 2004 entitled "System and Method of Owner Application Control of Electronic Devices" (11913-US-PRV-4214-25700); this application is also a continuation in part of U.S. patent application Ser. No. 13/606,814 filed Sep. 7, 2012 by Herbert A. Little, et al. entitled "System and Method of Owner Control of Electronic Devices" (10735-US-CNT[2]-4214-27116), which is a continuation of U.S. Pat. No. 8,302,185 issued on Oct. 30, 2012 entitled "System and Method of Owner Control of Electronic Devices" (10735-US-CNT-4214-27115), which is a continuation of U.S. Pat. No. 7,793,355 issued on Sep. 7, 2010 entitled "System and Method of Owner Control of Electronic Devices" (10735-US-PAT-4214-27101), which claims priority to and the benefit of U.S. Provisional Application No. 60/432,610 filed Dec. 12, 2002 entitled "System and Method of Owner Control of Electronic Devices" (10735-US-PRV-4214-27100), all of which are incorporated herein by reference as if reproduced in their entirety.

BACKGROUND

This system relates generally to electronic devices, and in particular to controlling application installation of such devices by a device owner.

In a corporate environment, employees are often provided with access to office supplies and equipment to be used in performing job functions. Standard equipment typically includes at least a personal computer (PC), and may also include wireless mobile communication devices and other types of electronic devices. Although such equipment is intended primarily for business or work-related purposes, users sometimes make personal use of office equipment. Employers may be comfortable with some degree of personal use of such equipment, provided that the personal use does not interfere with normal job functions, does not incur additional costs, and conforms with company policies.

In these types of situations, a user of an electronic device is not the owner of the device, and the user and owner may have different perceptions of acceptable device uses. Acceptable uses may be specified in company policies, for example, which employees are expected to follow, but beyond company policy statements, a corporate device owner often has little if any control over how electronic devices are ultimately used. According to one known scheme for controlling operation of electronic devices, an owner loads a policy file onto a device to restrict the type of operations or software applications that may be executed by the device. However, this type of scheme is sometimes

circumvented by a user by either deleting the owner policy file or replacing the owner policy file with a user policy file which may include fewer restrictions than the owner policy file. Therefore, there remains a need for a system and method of owner application control of electronic devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing a communication system in which electronic devices are used.

FIG. **2** is a block diagram illustrating a system of inserting owner information and owner control information onto an electronic device.

FIG. **3** is a block diagram of an electronic device in which a system and method of owner control are implemented.

FIG. **4** is a flow diagram illustrating a method of inserting owner information onto an electronic device.

FIG. **5** is a flow diagram illustrating a method of inserting owner control information onto an electronic device.

FIG. **6** is a flow diagram showing a method of owner control of an electronic device.

FIG. **7** is a block diagram of a wireless mobile communication device as an example of an electronic device.

FIG. **8** is a flow diagram illustrating a method of device initialization of required applications.

FIG. **9** depicts an exemplary user interface on a remote server for an owner to designate application control information for dissemination to particular devices, or groups of devices.

DETAILED DESCRIPTION

FIG. **1** is a block diagram showing a communication system in which electronic devices are used. The communication system **10** includes a Wide Area Network (WAN) **12**, coupled to a computer system **14**, a wireless network gateway **16** and a Local Area Network (LAN) **18**. The wireless network gateway **16** is also connected to a wireless communication network **20** in which a wireless mobile communication device **22** ("mobile device"), is configured to operate.

The computer system **14** is a desktop or laptop PC, which is configured to communicate to the WAN **12**, the Internet for example. PCs, such as the computer system **14**, normally access the Internet through an Internet Service Provider (ISP), Application Service Provider (ASP) or the like.

The LAN **18** is an example of a typical working environment, in which multiple computers **28** are connected in a network. It is normally located behind a security firewall **24**. Within the LAN **18**, a message server **26**, operating on a computer behind the firewall **24**, acts as the primary interface for the corporation to exchange messages both within the LAN **18**, and with other external messaging clients via the WAN **12**. Known message servers include, for example, Microsoft™ Exchange Server and Lotus Domino™. The LAN **18** includes multiple computer systems **28**, each of which implements a messaging client, such as Microsoft Outlook14, Lotus Notes™, Yahoo!™ Messenger, AOL Instant Messenger, or other client-server or peer-to-peer, or similar messaging clients with various architectures. Messages received by the message server **26** are distributed to mailboxes for user accounts addressed in the received messages, and are then accessed by a user through a messaging client operating on a computer system **28**. The fact that the example given illustrates a client-server architecture in no way implies that such architecture is necessary, as other architectures may be used.

Although only a message server **26** is shown in the LAN **18**, those skilled in the art will appreciate that a LAN may include other types of servers supporting resources that are shared between the networked computer systems **28**, and that the message server **26** may also provide additional functionality, such as dynamic database storage for data such as, but not limited to, calendars, to-do lists, task lists, e-mail and documentation. The message server **26** and electronic messaging are described for illustrative purposes only. Owner control systems and methods are applicable to a wide range of electronic devices, and are in no way limited to electronic devices with messaging capabilities.

The wireless gateway **16** provides an interface to a wireless network **20**, through which messages may be exchanged with a mobile device **22**. Such functions as addressing of the mobile device **22**, encoding or otherwise transforming messages for wireless transmission, and any other interface functions are performed by the wireless gateway **16**. The wireless gateway **16** may be configured to operate with more than one wireless network **20**, in which case the wireless gateway **16** also determines a most likely network for locating a given mobile device **22** and possibly track mobile devices as users roam between countries or networks.

The mobile device **22** is, for example, a data communication device, a voice communication device, a dual-mode communication device such as many modern cellular telephones having both data and voice communications functionality, a multiple-mode device capable of voice, data and other types of communications, a personal digital assistant (PDA) enabled for wireless communications, or a laptop or desktop computer system with a wireless modem.

Any computer system with access to the WAN **12** may exchange messages with the mobile device **22** through the wireless network gateway **16**. Alternatively, private wireless network gateways such as wireless Virtual Private Network (VPN) routers could be implemented to provide a private interface to a wireless network. A wireless VPN router implemented in the LAN **18** provides a private interface from the LAN **18** to one or more mobile devices such as **22** through the wireless network **20**. A private interface to a mobile device **22** may also effectively be extended to entities outside the LAN **18** by providing a message forwarding, or redirection system that operates with the message server **26**. Such a message redirection system is disclosed in U.S. Pat. No. 6,219,694, which is hereby incorporated into this application by reference. In this type of system, incoming messages received by the message server **26** and addressed to a user of a mobile device **22** are sent through the wireless network interface, either a wireless VPN router, the wireless gateway **16**, or another interface, for example, to the wireless network **20** and to the user's mobile device **22**. Another alternate interface to a user's mailbox on a message server **26** may be a Wireless Application Protocol (WAP) gateway. Through a WAP gateway, a list of messages in a user's mailbox on the message server **26**, and possibly each message or a portion of each message, may be sent to the mobile device **22**.

A wireless network **20** normally delivers messages to and from communication devices such as the mobile device **22** via RF transmissions between base stations and devices. The wireless network **20** may, for example, be a data-centric wireless network, a voice-centric wireless network, or a dual-mode network that can support both voice and data communications over the same infrastructure. Recently developed networks include Code Division Multiple Access (CDMA) networks and General Packet Radio Service (GPRS) networks. So-called third-generation (3G) networks like Enhanced Data rates for Global Evolution (EDGE) and Universal Mobile Telecommunications Systems (UMTS) are currently under development. Older data-centric networks include, but are not limited to, the Mobitex™ Radio Network ("Mobitex"), and the DataTAC™ Radio Network ("DataTAC"). Voice-centric data networks such as Personal Communication System (PCS) networks, including Global System for Mobile Communications (GSM) and Time Division Multiple Access (TDMA) systems, have been available in North America and world-wide for several years.

In the system **10**, a company that owns the LAN **18** may provide a computer system **28** and/or a mobile device **22** to an employee. When a computer system **28** issued to an employee is a laptop computer, for example, the computer system **28** may be used either within or outside the corporate LAN **18**. When the computer system is operating within the LAN **18**, non-local operations may be restricted by configuring permissions and restrictions for the computer system **28**, a network account of the user, or both, in such a way that the permissions and restrictions are not configurable by the user. However, if a user is using a computer outside the LAN **18**, by connecting the computer to the WAN **12** as shown at **14**, for example, network-based controls in place at the LAN **18** can sometimes be bypassed.

In order to maintain control over an electronic device such as the computer system **28** or mobile device **22**, an owner may establish local settings directly on the device. Such local settings control device operations, but only as long as the settings remain intact on the device. A common problem with this type of control mechanism is that local settings may be deleted, replaced, or otherwise altered by a user.

In some instances, the owner control information can include one or more applications lists. The application lists provide owner control of application installation and deletion on the electronic device. As an example, application lists can address different types of applications, such as but not limited to:

Required applications: These applications must be present on the device before the user may use the device; alternatively, one or more operations of the device can be disabled until such applications are available for execution on the device. This will allow the owner to install audit and remote administrative applications. The user can in some implementations be prevented from deleting these applications. This list may be small.

Allowable (or authorized) applications: These applications may or may not be present on a device. Thus the user is free to download these applications if they desire the functionality that the application provides. This list may be small.

Excluded applications: These applications may not be present on a device. Presumably an excluded application is a malicious application, or otherwise undesirable application. This list is potentially large.

With respect to allowed and/or required applications, even if the applications are required or allowed on the device, the owner may want to impose restriction on operations that such applications can perform. For instance, the owner may want to control functionality such as:

1) Is the application allowed to open network connections inside the firewall (e.g., via MDS)?

2) Is the application allowed to open network connections outside the firewall (e.g., via WAP, device TCP, SMS)?

3) Is the application allowed to open local connections (e.g., serial, IR, or USB connections)?

4) Is the application allowed to interact with other processes? Is the application allowed to access a Runtime Store or a Persistent Store?

5) Is the application allowed access to a telephone API (e.g., to make phone calls)?

FIG. **2** is a block diagram illustrating a system of inserting owner information and owner control information onto an electronic device; such an insertion system may be used in one or more implementations of the described owner application control systems and methods. The foregoing explanation is therefore exemplary in nature. The system in FIG. **2** includes an electronic device **210**, an owner information insertion point **220**, and an owner control information insertion point **230**. The owner information insertion point **220** is alternatively referred to as a branding point, while the owner control insertion point **230** is alternatively referred to as a control point. An owner information store **212**, an owner control information store **214**, and an interface/connector **216** are provided in the electronic device **210**. The owner information insertion point **220** includes an owner information source **224** and an interface/connector **222**. The owner control information insertion point **230** similarly includes an owner control information source **234** and an interface/connector **232**.

The owner information store **212** stores information, such as an owner name or other identification information, for example, which identifies an owner of the electronic device **210**. The owner control information store **214** stores information that is used to control the operation of the electronic device **210**. Owner control information may, for example, be specified in an authorization record that lists software applications authorized to be installed and executed on the electronic device **210**; authorization records can further constrain operations performed by installed applications. The use of owner control information to control operations of an electronic device is described in further detail below. The owner information source **224** and the owner control information source **234** could be local memory devices, communication modules through which remote memory devices storing owner information and owner control information are accessible, or possibly user interfaces through which owner information and owner control information are entered.

The interface/connector **222** is compatible with the interface/connector **216** to establish a communication link between the owner information insertion point **220** and the electronic device **210**, to thereby enable owner information to be transferred to the electronic device **210** from the owner information source **224**. The interface/connector **232** similarly enables transfer of owner control information from the owner control information source **234** onto the electronic device **210** via a communication link established between the interface/connectors **232** and **216**. The interface/connectors **216**, **222**, and **232** may establish wired communication links, where the interface/connectors are serial ports, for example, or wireless communication links such as infrared links where the interface/connectors are infrared modules. Owner information and owner control information transferred to a device are respectively inserted or stored in the owner information store **212** and the owner control information store **214**.

The owner control insertion point **220** is associated with an owner of the electronic device **210**. Where the electronic device **210** is provided to a user by an employer, for example, the owner control insertion point **220** may be a computer system or device controlled by a corporate computer system administrator or IT department. The electronic device **210** is "branded" with owner information by establishing a communication link between the owner information insertion point **220** and the electronic device **210** through the interface/connectors **222** and **216** and then inserting owner information into the owner information store **212**. Unless otherwise desired, once owner information has been inserted onto the mobile device **210**, then there can be a configuration such that only the owner or a party authorized by the owner is able to change the owner information or insert or change owner control information on the electronic device **210**.

Because insertion of owner control information onto the electronic device **210** is restricted once owner information has been inserted, the owner control information insertion point **230** need not necessarily be controlled by the owner of the electronic device **210**. When the owner maintains control over the owner control information insertion point **230**, the insertion points **220** and **230** may be implemented in the same computer system or device and share the same interface/connector. However, separate insertion points **220** and **230** as shown in FIG. **2** allow an owner of the electronic device to delegate owner control information insertion to a trusted entity. If owner control information insertion is controlled using digital signatures, for example, as described in further detail below, an owner first brands the electronic device **210** and provides the electronic device **210** and digitally signed owner control information to a user. In this case, the owner control information insertion point **230** may be the user's computer system, which is then used to insert the digitally signed owner control information onto the electronic device **210**.

In most implementations, the owner information insertion point **220** and the owner control information control point **230** include the same type of interface/connectors **222** and **232**, compatible with the interface/connector **216** in the electronic device **210**. However, the electronic device **210** may alternatively include multiple interface/connectors, such that different types of interface/connectors may be implemented at an owner information insertion point **220** and an owner control information insertion point **230**. Although only a single owner control information insertion point **220** and owner control information insertion point **230** are shown in FIG. **2**, a complete insertion system may include more than one of each type of insertion point. In a large company, for example, corporate computer system administrators may be authorized to perform owner information insertion operations from administrator computer systems, or from any corporate computer system from which administrative functions can be accessed, thereby providing multiple owner information insertion points **220**. Similarly, when an owner allows users to insert digitally signed owner control information onto electronic devices, as described above, each user's computer system may be used as an owner control information insertion point **230**.

The systems and methods of owner application control can use the insertion structures and methods described above; however, so long as owner control information store is capable of storing a required application list, and in some instances an allowed application list and/or an excluded application list, the particular control information insertion system and method can vary significantly, and use any conventional insertion/interfacing technology, without impacting the owner application control systems and methods discussed herein.

FIG. **3** is a block diagram of an electronic device in which a system and method of owner application control can be implemented. In FIG. **3**, the electronic device is a mobile

device **30** adapted to operate within a wireless network. Also shown in FIG. **3** is an insertion tool **64** used to insert owner information onto the mobile device **30**.

It should be apparent to those skilled in the art that only the components involved in an owner control system are shown in FIG. **3**. A mobile device typically includes further components in addition to those shown in FIG. **3**. Also, the mobile device **30** is an illustrative example of an electronic device for which an owner may wish to enforce some sort of usage policy. An owner may also wish to control the usage of other types of electronic devices, such as mobile telephones, laptop computers and PDAs, for example.

As shown in FIG. **3**, a mobile device **30** comprises a memory **32**, a processor **40**, an application loader **42**, an insertion module **44**, a user interface (UI) **46**, a wireless transceiver **48**, and an interface/connector **50**. The memory **32** can include a software applications store **34**, an owner information store **36**, an authorization record store **38**, as well as possibly other data stores associated with other device systems in addition to those shown in FIG. **3**.

The memory **32** is a writable store such as a RAM or Flash memory into which other device components may write data. However, write and erase access to the software application store **34**, the owner information store **36**, and the authorization record store **38** may be restricted, but need not be in all implementations. For example, a user of the mobile device **30** may be able to retrieve data from the stores **34**, **36**, and **38**, but write and erase operations for these stores are controlled, as described below. The software application store **34** includes software applications that have been installed on the mobile device **30**, and may include, for example, an electronic messaging application, a personal information management (PIM) application, games, as well as other applications. The owner information store **36** stores information such as an owner name or other identification, data integrity and source authentication information, such as a digital signature public key associated with a digital signature private key of the owner. Owner control information, in which an owner of the mobile device **30** specifies usage permissions and restrictions for the mobile device **30**, is stored in an authorization record in the authorization record store **38**. Such authorization records can include one or more of the aforementioned required, allowed and/or excluded application lists, or more specific operation constraints for specific allowed and/or required applications. It should be appreciated that the supported lists need not be stored as unit; rather, the lists can logically be formed from authentication records associated with individual applications, wherein the each application authentication records includes a field that designates the application appropriately (e.g., allowed, required, excluded, etc.) and can include a field containing an application identifier.

The processor **40** is connected to the wireless transceiver **48** and thus enables the mobile device **30** for communications via a wireless network. The application loader **42** and insertion module **44**, described in further detail below, are connected to the interface/connector **50** to allow communication with the insertion tool **64**, through the co-operating interface/connector **52**.

The UI **46** includes one or more UI components, such as a keyboard or keypad, a display, or other components which accept inputs from or provide outputs to a user of the mobile device **30**. Although shown as a single block in FIG. **3**, it should be apparent that a mobile device **30** typically includes more than one UI, and the UI **46** is therefore intended to represent one or more user interfaces.

The insertion tool **64** includes an owner information store **60** and an interface/connector **52** through which information is exchanged with the mobile device **30**, and thus represents an owner information insertion point **220** (FIG. **2**). As described above, an owner information insertion point such as the insertion tool **64** is normally controlled by an owner of an electronic device. Therefore, the insertion tool **64** is, for example, implemented on an administrator computer system used by an authorized administrator to enable services for or otherwise configure the mobile device **30**. Because networked computer systems can typically be used by any user, the insertion tool **64** may instead be accessible to any computer system in a corporate network, dependent upon the particular user that is currently "logged on" the computer system.

The owner information store **60** stores owner information to be inserted onto the mobile device **30**, and may be implemented, for example, on a local memory component such as a RAM chip, a flash memory device, or a hard disk drive. When the insertion tool **64** is implemented in a networked computer system or other network-connected device, the owner information store **60** may be a remote memory system such as a file server that is accessible to the insertion tool **64** through a network connection. The owner information store **60** may instead incorporate a memory reader such as a smart card reader, a memory card reader, a floppy disk drive, or a CD or DVD drive, for example.

Information is transferred between the insertion tool **64** and the mobile device **30** via a communication link established between the interface/connectors **50** and **52**. The interface/connectors **50** and **52** could be any of a plurality of compatible data transfer components, including, for example, optical data transfer interfaces such as Infrared Data Association (IrDA) ports, other short-range wireless communications interfaces, or wired interfaces such as serial or Universal Serial Bus (USB) ports and connections. Known short-range wireless communications interfaces include, for example, "Bluetooth" modules and 802.11 modules according to the Bluetooth or 802.11 specifications, respectively. It will be apparent to those skilled in the art that Bluetooth and 802.11 denote sets of specifications, available from the Institute of Electrical and Electronics Engineers (IEEE), relating to wireless LANs and wireless personal area networks, respectively. Therefore, a communication link between the insertion tool **64** and the mobile device **30** may be a wireless connection or a physical wired connection.

Because communications between the insertion tool **64** and the mobile device **30** need not necessarily be accomplished using a physical connection, references to connecting a mobile device to an insertion tool include establishing communications through either physical connections or wireless transfer schemes. Thus, the mobile device **30** could be connected to the insertion tool **64** by connecting serial ports on the mobile device **30** and the insertion tool **64**, by positioning the mobile device **30** such that an optical port thereof is in a line of sight of a similar port of the insertion tool **64**, or by connecting or arranging the mobile device **30** and the insertion tool **64** in some other manner so that data may be exchanged. The particular operations involved in establishing communications between a mobile device and an insertion tool are dependent upon the types of interfaces and/or connectors available in both the mobile device and the insertion tool.

Owner branding of the mobile device **30** may be facilitated by inserting owner information onto the mobile device **30** using the insertion tool **64** before the mobile device **30** is operable by a user. This may be accomplished, for example,

by pre-loading owner information before the mobile device **30** is provided to the user by the owner, or before the mobile device **30** is configured for use. In the former example, the owner maintains physical control of the mobile device **30** until owner information has been loaded, whereas in the latter example, the user has possession of the mobile device **30** but is in this example unable to make use of the device until it is configured by, or at least under the control of, the owner.

Pre-loading of owner information onto the mobile device **30** can be performed using the insertion tool **64**. The insertion tool **64** may be a computer system associated with an a owner system administrator, or a computer system which may be used by a mobile device user or administrator. Depending upon the owner information pre-loading scheme, the insertion tool **64** is operated by a mobile device user or an administrator.

When the mobile device **30** has been connected to the insertion tool **64**, owner information is retrieved from the owner information store **60** and transferred to the mobile device **30** through the interface/connectors **52** and **50**, and passed to the insertion module **44** on the mobile device **30**, which stores the owner information to the owner information store **36** in the memory **32**.

Although the insertion module **44** is shown in FIG. **3** as being connected to the interface/connector **50**, this module can be implemented as a software module or application that is executed by the processor **40**. As such, data transfers to and from the interface/connector **50** may actually be accomplished by routing data through the processor **40** to the interface/connector **50**. In this case, the processor **40** may be instructed by the insertion tool **64** to start the insertion module **44** before the owner information is transferred to the mobile device **30**. Alternatively, the processor **40** may be configured to start the insertion module **44** whenever owner information is received. The insertion tool **64** may similarly be a software module or application that is executed by a processor (not shown) in a computer system or device on which the insertion tool **64** operates.

The owner information that is pre-loaded onto the mobile device **30** may include data integrity and/or source authentication information, such as a cryptographic system like a digital signature public key which corresponds to a digital signature private key used by the owner to digitally sign information before it is transferred to the mobile device **30**. Pre-loading of the data integrity and/or source authentication information enables greater security of owner control operations, as described in further detail below in the context of digital signatures. Owner information may also include, for example, a name or other identifier associated with the owner of the mobile device **30**.

In an owner control scheme in which digital signatures are used to verify data integrity and authenticate a source of data, when the owner's digital signature public key has been inserted into the owner information store **36** on the mobile device **30**, owner control information, which specifies permissions and/or restrictions for the mobile device **30**, is inserted onto the mobile device **30**. Although an owner information insertion point, insertion tool **64**, is shown in FIG. **3**, it will be apparent from FIG. **2** and the above description that owner control information is usually inserted onto an electronic device after the device has been branded by inserting owner information onto the device. An owner control information insertion tool (not shown) configured for use with the mobile device **30** is similar to the insertion tool **64**, including an owner control information store and an interface/connector compatible with the interface/connector **50**. Owner control information is inserted onto the mobile device **30** and stored in the form of an authorization record in the authorization record store **38**. In an authorization record, an owner of the mobile device **30** specifies a list of software applications that a user is authorized to install on the mobile device **30**, as well as possibly a list of required software applications that must be installed on the mobile device **30**.

In order to prevent a user from inserting false owner control information to thereby circumvent owner control, owner control information can be digitally signed using the owner's digital signature private key before being transferred to the mobile device **30**. The insertion module **44** may be configured to verify the digital signature before the owner control information is stored on the mobile device **30**. If digital signature verification fails, then the owner control information is not stored on the mobile device **30**.

Digital signature schemes can involve some sort of transformation of digitally signed information to provide for checking the integrity of the information and authentication of a source of the signed information. For example, according to one known digital signature technique, a digest of information to be digitally signed is first generated using a non-reversible digest algorithm or transformation. Known digest algorithms include Secure Hashing Algorithm 1 (SHA-1) and Message-Digest algorithm 5 (MD5). Other digest techniques that produce a unique digest for each unique input may also be used. The digest is then further transformed using a digital signature private key and a signature algorithm to generate a digital signature. In digital signature verification, a digital signature public key corresponding to the private key is used.

In the context of owner control and owner control information, insertion of the owner's digital signature public key on a mobile device **30** as part of the owner information provides for digital signature-based security of owner control information. If some or all of the owner control information is digitally signed before transfer to the mobile device **30**, then the insertion module **44** can verify that owner control information has actually been signed using the owner's digital signature private key, known only to the owner, and that the owner control information has not been changed since it was signed. In this example, only owner control information that originates with the owner of a mobile device **30** is stored to and used on the mobile device **30**.

Owner control information is obtained by an owner control information insertion tool from an owner control information store, which may be a remote data store accessible to the insertion tool, a local store, or some form of memory reader, as described above. Owner control information is established based on a set of software applications or functions that the owner wishes to authorize on an electronic device, and may tend to change relatively infrequently once established. Such owner control information could then be digitally signed by a secure computer system or software component to which only administrators have access, using the owner's digital signature private key. In this case, signed owner control information is then stored at a location that is accessible to administrator computer systems and possibly other computer systems, and retrieved by an owner control information insertion tool as required. The owner control information insertion tool then transfers the signed owner control information to the mobile device **30**. Depending upon how often owner control information changes or is expected to change, the signed owner control information may be further distributed to each computer

system in a network in order to provide local access to signed owner control information. When new owner control information is generated and signed, the signed new owner control information can replace all existing copies of the owner control information, as described in further detail below. Wide distribution of owner control information provides easier access to the owner control information, whereas shared remote storage of owner control information requires fewer updates when new owner control information is established.

It is also possible to support digital signature generation for owner control information on an owner control information insertion tool. However, in the present example, this would require that the owner control information insertion tool has access to the owner's digital signature private key. Unless otherwise desired, digital signing of owner control information only by secure computer systems or components is generally preferred in that it limits the number of computer systems that can access the owner's digital signature private key.

When signed owner control information is transferred to the insertion module **44**, digital signature verification operations are performed. If the digital signature is verified, then the owner control information is stored on the mobile device **30** in the authorization record store **38**. Otherwise, the owner control information is not stored. In the event of a digital signature verification failure, an error or like indication may be output to a user on a UI **46** such as a display, an error message may be returned to the owner control information insertion tool, and an indication of the failure may also be output to a user of the owner control information insertion tool. When owner control information insertion fails, retry or other error processing operations may be performed on the owner control information insertion tool, the mobile device **30**, or both.

Given the importance of the owner digital signature public key in the present example, at least a first owner information insertion operation for any mobile device **30** is preferably either performed or at least authorized by an administrator, in order to ensure that accurate owner control information is inserted onto the mobile device **30**. This prevents a user from circumventing owner control by inserting a digital signature public key other than the owner's digital signature public key onto the mobile device **30**.

When owner control information changes, where an owner wishes to expand or further restrict the use of an electronic device, for example, any existing owner control information may be replaced. As described above, new owner control information may be digitally signed, and the signed new owner control information is distributed to one or more locations from which it is retrieved for insertion onto electronic devices.

Any of several mechanisms for subsequent distribution of signed new owner control information to electronic devices are possible. When new owner control information is distributed to each owner control information insertion tool, the insertion tool may be configured to detect receipt of new owner control information, and to transfer the new owner control information to the mobile device **30** the next time the mobile device **30** is connected to the owner control information insertion tool. As described above, an owner control information insertion point **230** (FIG. **2**), such as an owner control information insertion tool, may be controlled by a user of an electronic device. Many modern electronic devices are configured to be synchronized with computer systems. In such systems, this type of owner control information distribution may be supported by implementing an owner information control insertion tool in a user's computer system. New owner control information is then transferred to the electronic device the next time the electronic device is synchronized with the computer system.

Alternatively, signed new owner control information may be sent by an owner to all owned mobile devices through a wireless network, via the LAN **18**, the WAN **12**, and the wireless network gateway **16**, as shown in FIG. **1**, for example. Such signed owner control information could be sent to the owned mobile devices either directly or through one or more owner control information insertion tools. Although the owner's digital signature public key may be initially transferred to a mobile device **30** through the interface/connectors **52** and **50**, other communication links which cannot be physically secured or protected, such as wireless or public communication network links, may be used to subsequently transfer signed owner control information to an electronic device that is enabled for communications over such other links. When the owner's digital signature public key has been inserted on a mobile device **30**, the insertion module **44** is able to verify both the integrity and the source identity of any signed owner control information received, whether it is received via the interface/connector **50** or the wireless transceiver **48**. In this type of implementation, for example, an owner control information insertion tool may include a different type of interface to the mobile device **30** than the owner information insertion tool **64**.

Initial storage of owner control information, as well as replacement of existing owner control information, is in this example thereby dependent upon verification of a digital signature by the insertion module **44**. Other checks may also be performed before existing information is replaced. In order to prevent replay attacks, in which old owner control information is received by the electronic device, owner control information can include version information. A configuration can include an existing owner control information being replaced only where received owner control information is newer than the existing owner control information. Generally, newer owner control information has a higher version number.

Although owner information is inserted onto the mobile device **30** using the insertion tool **64** as described above, changes to existing owner information, such as when the owner's digital signature private/public key pair is changed, may alternatively be updated on the mobile device **30** using digital signature techniques. To this end, the insertion tool **64** may include other types of communication modules (not shown), such as a wireless transceiver or network connector, for example, that are less secure than the interface/connector **52**. In that case, any such updates are dependent upon verification of a digital signature using a digital signature public key in existing owner information.

The foregoing description relates primarily to writing owner information and owner control information to memory on an electronic device such as the mobile device **30**. However, an owner may also wish to erase owner information and owner control information, without replacing existing information with new information. In this case, because information is not being written to memory on a device, no signed owner information or owner control information would be sent to the device. Instead, an erase command or request may be sent to the device. Erasure may be a further function supported by the insertion module **44**.

Referring again to FIG. **3**, if owner information is to be erased from the owner information store **36**, then an erase command or request is digitally signed and sent to the

insertion module **44**. As with new owner information or owner control information, a signed command or request could be sent to the mobile device **30** through either the interface/connector **50** or the wireless transceiver **48**. The insertion module **44**, using the owner's digital signature public key, executes the command or completes the request if a digital signature is verified. Otherwise, the command or request may be ignored, and an error or failure indication may be displayed to a user on a UI **46** on the mobile device **30**, returned to a sending system or device that sent the command or request, or both. Further error or failure processing routines may then be performed at the sending system or device.

Since owner information includes the owner's digital signature public key in a signature-based owner control scheme, erasure of owner information can be tightly controlled. For example, only owner system administrators may be authorized to send erase commands or requests. Sending of signed commands or requests to the mobile device **30** can be restricted to administrator computer systems or accounts, an owner information insertion tool, or an owner-controlled erasure tool. For example, an insertion tool such as the insertion tool **64** could be adapted to erase existing owner information from the mobile device **30** by providing an erase command generator or store which is also coupled to the interface/connector **52**. Alternatively, owner information erasure could be accomplished using a specialized, owner-controlled erasure tool incorporating such an erase command generator or store and an interface to the mobile device **30**. Erasure of owner control information can be controlled in a similar manner.

Where an owner control system is configured to support erasure and possibly other owner information and owner control information management functions, access to the owner's digital signature private key may be restricted in order to control the information, requests, and commands that can be digitally signed and sent to an electronic device. The digital signature private key or digital signature generation functions may be accessible only to specific computer systems or administrator login accounts, for example.

As shown in FIG. **3**, other systems on the mobile device **30** can have access to the memory **32**. Configurations may be used wherein no device system is able to insert, change, or erase owner information or owner control information without submitting properly signed information or commands. Any data stores, such as the owner information store **36** and the authorization record store **38**, that store owner information or owner control information can therefore be located in protected memory areas. Configuration may be used where only the insertion module **44** has write and erase access to these stores, such that digital signature-based control of insertion and erasure of owner information and owner control information are maintained. Other device systems have read only access to owner information and owner control information. In one possible implementation, any systems or components through which the memory **32** is accessible are configured to allow memory read operations from any locations in the memory **32**, but deny any write or erase operations to memory locations storing owner information or owner control information unless the operations originate with or are authorized by the insertion module **44**. In an alternative implementation, a memory manager (not shown) is provided to manage all memory access operations. Such a memory manager is configured to direct any write or erase operations involving owner information or owner control information stores to the insertion module **44** for digital signature checking and authorization before completing the operations. Owner information and owner control information may thereby be read by other device systems, but preferably may only be inserted, changed, or erased when a digital signature is verified.

It should be appreciated that the above public key digital signature operations are intended only as an illustrative example. Other digital signature schemes, or other data integrity checking and source authentication schemes, may instead be used to verify the integrity and source of owner control information or commands. Further, the authentication and security described herein above can be used to transfer the owner application control information; however, various systems and methods of owner application control need not use authentication and/or secure transmission in order to achieve the desired owner application control as described herein.

In the mobile device **30**, owner control information is included in an authorization record that is stored in the authorization record store **38**. An authorization record specifies particular software applications that are authorized for installation on the mobile device **30**, and may also specify required software applications that must be installed on the mobile device **30**. Such an authorization record provides an electronic device owner with relatively tight control of how a user makes use of the mobile device **30**, since only authorized software applications can be loaded onto the device.

For authorized and/or required applications, some systems can provide a more fine grained control within the authorization record(s). In such systems, the owner can provide more specific controls on the operations that installed application can perform. Such controls can be specified on an individual application basis, or in some cases by groups of applications. Such operation controls can determine whether an application can connect to external resources, and if so, the channels (that may be used for such connections) can communicate with other applications executing on the device and/or can access part or all of local memory on the device.

Software application loading operations are enabled on the mobile device **30** by the application loader **42**. As described above in regard to the insertion module **44**, although the application loader **42** is shown as being connected to the interface/connector **50**, information may actually be exchanged between the application loader **42** and the interface/connector **50** or the wireless transceiver **48** through the processor **40**.

Like owner information and owner control information, software applications may be received by the mobile device **30** via the interface/connector **50** or the wireless transceiver **48**. One possible source of software applications configured for operation on the mobile device **30** is a user's computer system equipped with an interface/connector compatible with the interface/connector **50**. When the computer system is connected to a corporate LAN, for example, software applications provided by a corporate owner of the mobile device **30** may be retrieved from a file server on the LAN or other store on the LAN, and transferred to the mobile device. A computer system may also or instead obtain software applications for the mobile device **30** from a local store, or other sources, such as Internet-based sources, with which the computer system may communicate.

The application loader **42** may be configured to determine whether owner control information is stored on the mobile device **30** whenever a software application is received. If no owner control information is present on the mobile device **30**, then no owner controls have been established for the

mobile device **30**, and the software application is installed. Alternatively, the application loader **42** could consult a remote server for an owner control information update prior to attempting the installation. Software application installation typically involves such operations as storing a received application file to the software application store **34** in the memory **32**, extracting files for storage to the software application store **34**, or possibly executing an installation program or utility. If owner control information is subsequently inserted onto the mobile device **30**, existing software applications may be checked by either the application loader **42** or the insertion module **44** to ensure that all software applications resident on the mobile device **30** are authorized software applications. Any software applications that have not been authorized are erased from the mobile device **30** or otherwise rendered inoperable.

In some circumstances, owner information may have been inserted onto an electronic device, but owner control information has yet to be inserted. In order to prevent loading of a software application onto the mobile device **30** that subsequently inserted owner control information does not authorize, the mobile device **30** may be substantially disabled, permitting only a limited subset of device functions to be executed, until owner control information is inserted. Alternatively, the application loader **42** may be configured to determine whether owner information is present on the mobile device **30** when a software application is received. Where owner information is found, indicating that owner control information will be established and used for the mobile device **30**, the application loader **42** then determines whether owner control information has been inserted. In the event that owner information but not owner control information is found, the application loader **42** does not load the received software application. Error processing operations may then be performed, such as purging the received software application from any temporary memory location in which it was stored when received, and, if memory resources on the mobile device **30** permit, storing the received software application on the mobile device **30** in such a way that it is not executable. Any software applications stored in this manner are then processed by the application loader **42** when owner control information is inserted onto the mobile device **30**. Although software applications are stored on the mobile device **30** in this example, they would not be usable until owner control information is inserted onto the mobile device **30**, and it is confirmed that the software applications are authorized for installation. The amount of memory space made available for such software applications may occupy can be limited, so that available memory space will not be depleted by storing unchecked and possibly unauthorized software applications.

When the application loader **42** determines that owner control information has been inserted onto the mobile device **30**, the application loader **42** then determines whether the received software application is authorized for installation on the mobile device **30**. If the owner control information includes an authorized software application list, the application loader **42** searches the list to determine whether the received software application is one of the authorized software applications. Alternatively, an authorized (allowed) software application list residing on a remote or external device (e.g., remote computer system, external card or memory device, etc.) can be consulted to determine whether a particular application is authorized for installation. In some such cases, the approval response from the remote or external device can include the application for installation, or information from which a source for the to-be installed application can be obtained; upon receipt, the device can download and/or install the application based upon the received approval response.

An authorized software application list can include information that uniquely identifies the authorized software applications, such as a hash of the software application source code or executable code, for example. Because a software application developer is free to choose a file name for any software application, file names may not provide a reliable authorization check. However, if an owner generates a hash of each authorized software application and includes the hash in the owner control information that is inserted onto the mobile device **30**, then only particular versions of authorized software applications can be installed on the mobile device **30**. The application loader **42** generates a hash of any received software application, and installs the software application only if the generated hash matches a hash in the owner control information. In order to support different hashing algorithms on different electronic devices, a device owner generates more than one hash of each software application and includes each hash in the owner control information inserted onto each owned electronic device. An electronic device may then use any of a number of different hashing algorithms to generate a hash of a received software application. Other unique transformations than hashes could also be used to generate owner control information and to determine whether received software applications are authorized for installation.

In some instances, prior to checking the authorized application list, at periodic intervals or upon a remote authorization change, the device can receive an authorized application list, or an authorized application list update, from a remote server or external device controlled by the device owner. The list or list update can be received in response to a request by the device (e.g., request a list or update upon installation attempt) or without such a request (e.g., responsive to an authorization modification by the owner on a remote owner administration server). Upon receipt of an authorized list, the device can install the list overwriting any prior list; upon receiving an update, the update is processed and integrated into an existing list, or used to create a list if none was present prior. In some instances the secure insertion tools, and/or other encryption/authentication, approaches as described herein can be used to provide the authorized application list to the device.

Owner control information may also include a required software application list that uniquely identifies software applications that the owner of an electronic device establishes as mandatory; alternatively, such a required software application list could reside on a remote or external device (e.g., remote computer system, external card or memory device, etc.) that can be consulted at need. A required software application list allows an owner to ensure that every owned electronic device supports certain core functions, such as electronic messaging and secure communications, for example.

Software applications in a required software application list may be uniquely identified by one or more hashes, as described above in the context of authorized applications. The processor **40**, application loader **42**, insertion module **44**, or a further device component or system is configured to periodically check to ensure that each required software application is present on the mobile device **30**, and that a hash of each required software application matches a hash in the required software application list. In addition, or instead, at power up or other initialization of the device, presence of required applications can be checked. Where a required

software application is not present on the device or its hash does not match a hash in the required software application list, which would occur when a software application has been changed, the mobile device **30**, or at least some of its functions, can be rendered unusable. Alternatively, the mobile device **30** can download and install missing or corrupted applications transparently to the user of the device; after successful installation of all required programs, the device is restored to operability.

In some instances, device initialization may include use of the required software application list. Such a process is shown in FIG. **8**. A determination is made as to whether required applications are available on the device in step **800**. The device examines installed applications to determine if applications on the required software application list are available on the device. This can occur through examination of the required software application list residing in the owner control information store. Alternatively, identification information associated with installed applications can be transmitted to a remote server managed by the owner that performs the comparison and returns the results of such a comparison to the device. If required applications are missing the device is disabled in part, or in whole, in step **810**. The device may transparently initiate download of required applications that were determined to be unavailable **820**. In implementations using a remote server to perform the comparison, some such implementations may allow the remote server to directly return any missing applications to the device. When all required applications are present the device operates normally **840**.

Prior to checking for the presence of required applications, at periodic intervals or upon a remote authorization change, the device can receive a required list, or a required list update, from a remote server or external device controlled by the device owner. The list or list update can be received in response to a request by the device (e.g., request a list or update at initialization) or without such a request (e.g., responsive to an authorization modification by the owner on a remote owner administration server). Upon receipt of a required list, the device can install the list overwriting any prior list; upon receiving an update, the update is processed and integrated into an existing list, or used to create a list if none was present prior. In some instances the secure insertion tools, and/or other encryption/authentication, approaches as described herein can be used to provide the required application list to the device.

In order to provide further control over required software applications, erasure or other operations involving such applications are controlled. Digital signature-based control of such functions is implemented by requiring a digital signature on any erase or write command that affects a required software application. When an erase or write command is received from a system on the mobile device **30** or from a remote system via the interface/connector **50** or wireless transceiver **48**, the processor **40** or another device system such as a memory manager (not shown) determines whether the command involves the software application store **34**. Such a write or erase command is not executed unless a digital signature is verified using the owner's digital signature public key stored on the mobile device **30**. Although software applications may be executed by device systems without requiring digital signatures, required software applications, if so desired, may only be changed or erased when a digital signature is verified. As above, digital signatures represent one possible data integrity and source authentication mechanism.

Owner control information may also include an excluded software application list that uniquely identifies software applications that the owner of an electronic device establishes cannot be installed on the device. An excluded software application list allows an owner to ensure that every owned electronic device does not contain particular malicious and/or counter productive software applications. Software applications in an excluded software application list may be uniquely identified by one or more hashes, as described above in the context of authorized applications. The processor **40**, application loader **42**, insertion module **44**, or a further device component or system is configured to periodically check to ensure that no excluded software application is present on the mobile device **30**, and that a hash of each present software application does not match a hash in the excluded software application list. Where an excluded software application is present on the device or its hash does match a hash in the excluded software application list, which would occur when a software application has been changed, the mobile device **30**, or at least some of its functions, can be rendered unusable. Alternatively, the mobile device **30** can delete an excluded application found present on the device transparently to the user of the device; after successful deletion, the device is restored to operability.

In many cases, the excluded application list can be maintained remotely on a remote server or on an external memory device rather than in a memory area local to the device. In such instances, application loader can transmit a request to the remote server or search the external memory device (e.g., memory card, network attached disk, etc.). In such cases, the remote server consults the excluded list, or the device searches the external memory device, to determine whether the to-be installed application has been designated as excluded. In the case of a remote server, the remote server would transmit to the device either an approval or a denial as appropriate. The device could determine approval or denial directly from its consultation of an external memory device.

When an application installation request is received by a device supporting an excluded application list, the excluded application list is consulted based upon the application to-be installed. If the application to-be installed is found on the excluded application list, the installation request is denied and the application is not installed on the device. In machines supporting an allowed list and/or a required list in addition to an excluded list, a list priority could be established to determine how the device handles installation requests for applications that are on multiple lists. For instance, if a particular application appears on both the required list and the excluded list, a conflict exists. A priority scheme can be used to resolve such conflicts. In one such scheme, if an application is on the required list, its presence on other lists is not considered; if an application is on the authorized list and the excluded lists, then the application is considered excluded as the more conservative approach.

In instances where allowed, required and/or excluded lists are supported, some or all these lists can be maintained locally within the devices owner control information store; alternatively, one or more supported lists could be maintained remotely or on an external memory device.

FIG. **4** is a flow diagram illustrating a method of inserting owner information onto an electronic device; this method may be used in connection with inserting the owner application control information onto the electronic device. The method in FIG. **4** begins at step **72**, when an electronic device owner establishes owner information. This involves

such operations as selecting an owner name or identifier and generating or obtaining an owner digital signature private/public key pair, for example. The owner information is then digitally signed and sent to the electronic device at step **74**.

At step **76**, a determination is made as to whether owner information already exists on the electronic device, by checking an owner information store, for example. When owner information does not exist on the electronic device, such as for an initial insertion of owner information, the owner information is inserted onto the electronic device at step **84**, by storing the owner information to a memory on the electronic device. When the owner information is initially being inserted onto the electronic device, it need not necessarily be digitally signed. As described above, initial owner information insertion may be performed directly by or at least under the authorization of the owner or an owner system administrator.

A digital signature associated with the owner information is checked at step **78** where owner information already exists on the electronic device. If the digital signature is not verified, as determined at step **80**, the owner information cannot be inserted onto the electronic device, and error processing is invoked at step **82**. As described above, error processing may include such operations as indicating an error or failure on a UI of the electronic device and sending an error or failure message to an insertion tool or system from which the owner information was sent. The owner information is inserted onto the electronic device at step **84** where the digital signature was verified.

Once owner information has been inserted onto an electronic device, owner control information is inserted onto the electronic device to set up owner controls. FIG. **5** is a flow diagram illustrating a method of inserting owner control information onto an electronic device.

At step **92**, owner control information is established, based on how an owner wishes to control an electronic device. Owner control information, as described above, may include an authorized software application list and a required software application list, for example. The owner control information is then signed and sent to the electronic device at step **94**. The digital signature on the owner control information is then checked at step **96**. At step **98**, it is determined whether the digital signature is verified. Error processing, which may involve operations similar to those described above in conjunction with step **82** in FIG. **4**, is performed at step **100**. If owner information including the owner's digital signature public key has not been previously inserted onto the electronic device, or the owner control information was not signed using the digital signature private key corresponding to the owner digital signature public key inserted onto the electronic device, then the digital signature is not verified at step **98**.

When the digital signature is verified at step **98**, it is then determined at step **101** whether the received owner control information is current, such as by determining whether a version number of the received owner control information is greater than the version number of existing owner control information. The owner control information is inserted onto the electronic device at step **102** when the digital signature was verified and the received owner control information is current, by storing the information to an appropriate data store on the electronic device, for example. Otherwise, error processing is performed at step **100**.

Other operations may also be dependent upon verification of digital signatures. For example, commands or requests to write data to or erase data from an owner information store, an owner control information store, or a software application store may be similarly processed to verify associated digital signatures before the commands or requests are completed.

The owner control information, such as the software application lists and the application operation restrictions described above, can be maintained on a remote server managed by the device owner. The remote server can maintain a device data store, that may be in the form of a database, that stores the control information, including application control information, associated with owned devices.

For each device, or for groups of devices, particular application lists (e.g., required, authorized and/or excluded) and allowable operations for particular applications can be created, modified, stored and distributed. In some implementations, a graphical user interface can be provided through which the owner can specify the particular control information associated with a device or device group.

Owner control information regarding particular applications can be provided to the electronic device from a remote source (e.g., remote computer system server, local memory device such as memory card or disk, etc.) via a wired (or other direct connection based upon physical contact of the device with the source) or a wireless (e.g., IR, 802.11, Bluetooth, etc.) communication channel. In such cases, the policy information including installation constraints and/or application operation constraints can be provided in a predefined format. The received policy information can then be used to create, update and/or delete authentication records.

In one implementation, the following format can be used to encode the owner control information regarding an application:

<encoding>=<version><connection set>*<cod file data>*

<version> is a byte. The current version is 0.

<connection set>=a UTF8 string of comma separated domains

<cod file data>=<hash><flags><internal connections set index (a byte)><external connections set index (a byte)>

The download default is specified by a cod file data with a hash of all zeros.

<hash> is a 20 byte SHA1 hash of the cod file

<flags> is a 32 bit int.

Required App=1
Excluded App=2
Inter-Process Communication Allowed=4
Internal Network Connections Allowed=8
External Connections Allowed=16
Local Connections Allowed=32

The policy information associated with specific applications can be stored either on a remote server or memory device for delivery to the electronic device. Such storage can in some instances conform to the above described format. The policy information can be for an application can be associated with a particular electronic device or a particular group of electronic devices. Alternatively, some or all of such policy information can be stored remotely and queried upon request from the device.

FIG. **9** depicts one possible user interface provided via a remote server for an owner to configure application policy information for particular applications. In this particular example interface, particular groups of electronic devices by device type have particular owner control information associated therewith for particular applications. An information technology manager for the device owner can control the policy for a given set of devices by changing the provided configuration information. Such changes could then be transmitted to individual devices. In the depicted example,

the application list is being used in the context of constructing a "target configuration" in which the handheld will be required to have the browser and security applications, as well as the phone application, but the memo pad and tasks applications are optional (allowed but not required). A user can select a row as shown at **900** in order to modify one or more of the values associated with an entry.

A remote server can be used to store owner control information associated with one or more electronic devices, or groups of devices. The remote server can communicate with the one or more devices via any suitable communication channel (e.g. wired or wireless connection). The remote server can use owner control information insertion tools as described herein. The owner control information on the remote server can be managed in a variety of ways including through provision of a management user interface such as the one depicted in FIG. **9**. The management user interface can be provided directly by the remote server, or alternatively be provided by a computer system that communicates with the remote server.

As has been discussed previously, the required, allowed and/or excluded application lists can be either locally or remotely (including an external memory device) queried, depending upon particular implementation. In either case, the supported lists can be maintained by a remote server that the owner could control. In the case of an external memory device used for list consultation, the memory device could be a shared access device (e.g., network disk) accessible by the device and an owner management system, or the memory device could be a removable media or memory card that is temporarily connected to either the remote server, or a separate management system in communication with the remote server. In the latter case, list information would be stored on the memory device for later insertion or access by the owner controlled device.

If lists are locally maintained, the device may periodically or upon occurrence of specific events (e.g., initialization, installation request, etc.) query the remote server for a list or list update. Upon receipt of a request by the remote server, the server would determine the list appropriate for the requested device based upon device type and/or an individual device identifier. The remote server would then transmit the determined list or list update to the requesting device. A server side change to the list could trigger an unsolicited push of the list to the device. In which case, the server would determine impacted devices based upon the server side change and transmit the list or list update to the impacted devices.

Owner control information is then used to control the electronic device. FIG. **6** is a flow diagram showing a method of owner control of an electronic device. At step **110**, an operation request is received at the electronic device. Operation requests include, for example, receipt of a software application for installation, a function call from a software application executing on the electronic device, an attempt by a user, software application, or a system on the electronic device to perform an operation, and the like. Such requests may originate with a user, a software application, a device system, or possibly a remote system or device. If owner information does not exist on the electronic device, as determined at step **112**, then owner controls have not been established and the operation is performed at step **122**. In the example of a received software application, step **122** involves installation of the software application on the electronic device.

When owner information exists, it is determined at step **114** whether owner control information exists. Error processing operations are performed at step **116** if owner information, but not owner control information, exists. As described above, determining whether owner information exists at step **112**, and then reverting to error processing at step **116** where it is determined at step **114** that owner control information does not exist prevents certain operations, such as software application loading and installation, when an owner information has been inserted onto an electronic device, but owner control information has not yet been inserted. Step **116** may include such operations as presenting an error message to a user of the electronic device and returning an error indication to a source from which the operation request was received. Alternatively, a default action in response to a negative determination at step **114** could be to revert to step **122**, when an owner does not wish to restrict device operations before owner control information is inserted.

When both owner information and owner control information have been inserted onto an electronic device, it is determined at step **118** whether the operation is permitted. In the case of a received software application, step **118** involves determining whether software application installation is permitted, and possibly whether the software application is an authorized software application. In the case of authorized applications, the requested operation could include, for example, an application requesting opening a connection (e.g., network connection—MDS, WAP, SMS, TCP, etc. or local—USB, serial, etc.), accessing the telephone API, accessing local memory or communicating with other applications executing on the device. The operation is performed at step **122** where the operation is permitted. Otherwise, error processing is performed at step **120**. As described above, owner control information may include not only permissions and restrictions for electronic device operations and software applications, but also a list of required software applications or modules which may be checked from time to time to ensure that all required software applications are present on an electronic device. For example, an electronic device may be configured to check for required software applications at step **118** when certain types of operation requests are received, and to perform the operation at step **122** only when all required software applications are found.

It will be appreciated that the above description relates to the invention by way of example only. Many variations on the systems and methods described above will occur to those knowledgeable in the field, and such variations are within the scope of this application, whether or not expressly described. As an example, a system of owner application control of an electronic device can comprise an owner control information store configured to store owner control information for controlling operation of the electronic device, and more specifically installation and/or deletion of applications on the electronic device and/or restrictions on operations by applications once installed. The owner control information can comprise a list of one or more required applications. In some instances, the owner control information can further comprise a list of one or more allowed applications and/or a list of one or more excluded applications. The owner control information store can reside on the controlled device or on one or more remote servers; alternatively, portions of the owner control information store can be distributed between the controlled device and one or more remote servers. In addition to, or instead of, the required list, the allowed list and/or the excluded list, the owner control information can comprise one or more constraints that control operations that can be performed by an application or a group of applications.

A method of owner application control may include variety of steps that in some implementations can be in the form of computer executable instructions stored on one or more computer readable media and/or be distributed via one or more data signals. Such a method can includes verifying that an application in a required list in an owner control information store is available for execution on the device, and if the application in the required list is not verified as available, initiating download and installation of such application from an external application source such as a computer system or memory device. The electronic device can in some instances be disabled from operating normally until applications on the required list are available for execution on the device. More specifically, at least one operation of the device can be disabled until the required application is available for execution.

As another example, a method may in some instances include steps of storing owner information having a required list having data integrity and/or source authentication information on an electronic device, receiving owner control information at the electronic device, and checking integrity of the received owner control information and/or determining whether the authorized source is authentic.

In addition to, or instead of, the steps provided above, a device can perform the steps of receiving an operation request from an application and determine whether the application is allowed to perform the requested operation based upon owner control information associated with the application. The requested operation is only executed if the requested operation is determined to be allowed for the application.

As yet another example, a system can be configured for owner application installation control of an electronic device. An owner control information store can be configured to store owner control information having a required list identifying one or more applications required for full operation of the electronic device. Initialization processor instructions (e.g., as implemented in a software module, etc.) can be used to consult (e.g., directly or indirectly have access to) owner control information in the owner control information store in order to verify if an application in the required list is available for execution on the electronic device. An application loader module that is invoked by the initialization instructions when the application in the required list is not available for execution and that downloads the application from an external application source and installs it on the electronic device. Operation control instructions can be used to disable at least one operation of the electronic device until the application loader module completes installation of the application.

A method may also be configured for designating owner contral of application operations for an electronic device by receiving an operation indication of one or more operations associated with a particular application; generating an authorization record based upon the received operation indication and the particular application; storing the generated authorization record; receiving a device indication of one or more electronic devices subject to owner control; receiving a correspondence indication that associates the received device indication with one or more stored authorization records; and communicating one or more stored authorization records to one or more electronic devices based upon the received device indication and the received correspondence indication.

Still further as another example, owner information and owner control information operations may be secured by other means than digital signatures. Instead of checking digital signatures on owner information, owner control information, and restricted commands or requests, an electronic device might issue a cryptographic challenge using a previously inserted encryption key associated with the owner. The encryption key could be a public key of the owner or a secret key shared between the owner and the electronic device. Operations such as owner information or owner control information insertion or erasure would then be performed only when a valid challenge response is returned. A valid challenge response may only be generated using a corresponding encryption key. Data integrity and source authentication could instead be assumed, for example, where owner information and owner control information are sent to an electronic device over a secure channel. If the device properly decrypts information received via the secure channel, then it is assumed that the information is valid and was sent by an authorized source. In this latter scheme, the source and device share a public/private key pair, or a common symmetric key.

In some instances, owner control information such as owner application control information can reside on a remote server rather than on the electronic device. For instance, one or more of a required, authorized and/or excluded application list can reside on a remote server. In such instances, an operation request such as application installation or device initialization can generate a query to the remote server where such lists reside. The proper list can be consulted and an appropriate response returned to the inquiring device.

In addition, an electronic device in which systems and methods described above are implemented may include fewer, further, or additional components than shown in FIGS. **2** and **3**. FIG. **7** is a block diagram of a wireless mobile communication device as an example of such an electronic device. However, it should be understood that the systems and methods disclosed herein may be used with many different types of devices, such as personal digital assistants (PDAs) and desktop computers.

As shown in FIG. **7**, mobile device **500** is preferably a two-way communication device having at least voice and data communication capabilities. The mobile device **500** preferably has the capability to communicate with other computer systems on the Internet. Depending on the functionality provided by the mobile device, the mobile device may be referred to as a data messaging device, a two-way pager, a cellular telephone with data messaging capabilities, a wireless Internet appliance, or a data communication device (with or without telephony capabilities).

The mobile device **500** includes a transceiver **511**, a microprocessor **538**, a display **522**, non-volatile memory **524**, random access memory (RAM) **526**, auxiliary input/output (I/O) devices **528**, a serial port **530**, a keyboard **532**, a speaker **534**, a microphone **536**, a short-range wireless communications sub-system **540**, and may also include other device sub-systems **542**. The transceiver **511** preferably includes transmit and receive antennas **516**, **518**, a receiver (Rx) **512**, a transmitter (Tx) **514**, one or more local oscillators (LOs) **513**, and a digital signal processor (DSP) **520**. Within the non-volatile memory **524**, the mobile device **500** includes a plurality of software modules **524**A **524**N that can be executed by the microprocessor **538** (and/or the DSP **520**), including a voice communication module **524**A, a data communication module **524**B, and a plurality of other operational modules **524**N for carrying out a plurality of other functions.

The mobile device **500** is preferably a two-way communication device having voice and data communication capa-

bilities. Thus, for example, the mobile device **500** may communicate over a voice network, such as any of the analog or digital cellular networks, and may also communicate over a data network. The voice and data networks are depicted in FIG. **7** by the communication tower **519**. These voice and data networks may be separate communication networks using separate infrastructure, such as base stations, network controllers, etc., or they may be integrated into a single wireless network. References to the network **519** should therefore be interpreted as encompassing both a single voice and data network and separate networks.

The communication subsystem **511** is used to communicate with the network **519**. The DSP **520** is used to send and receive communication signals to and from the transmitter **514** and receiver **512**, and also exchange control information with the transmitter **514** and receiver **512**. If the voice and data communications occur at a single frequency, or closely-spaced set of frequencies, then a single LO **513** may be used in conjunction with the transmitter **514** and receiver **512**. Alternatively, if different frequencies are utilized for voice communications versus data communications or the mobile device **500** is enabled for communications on more than one network **519**, then a plurality of Los **513** can be used to generate frequencies corresponding to those used in the network **519**. Although two antennas **516**, **518** are depicted in FIG. **7**, the mobile device **500** could be used with a single antenna structure. Information, which includes both voice and data information, is communicated to and from the communication module **511** via a link between the DSP **520** and the microprocessor **538**.

The detailed design of the communication subsystem **511**, such as frequency band, component selection, power level, etc., is dependent upon the communication network **519** in which the mobile device **500** is intended to operate. For example, a mobile device **500** intended to operate in a North American market may include a communication subsystem **511** designed to operate with the Mobitex or DataTAC mobile data communication networks and also designed to operate with any of a variety of voice communication networks, such as AMPS, TDMA, CDMA, PCS, etc., whereas a mobile device **500** intended for use in Europe may be configured to operate with the GPRS data communication network and the GSM voice communication network. Other types of data and voice networks, both separate and integrated, may also be utilized with the mobile device **500**.

Communication network access requirements for the mobile device **500** also vary depending upon the type of network **519**. For example, in the Mobitex and DataTAC data networks, mobile devices are registered on the network using a unique identification number associated with each device. In GPRS data networks, however, network access is associated with a subscriber or user of the mobile device **500**. A GPRS device typically requires a subscriber identity module ("SIM"), which is required in order to operate the mobile device **500** on a GPRS network. Local or non-network communication functions (if any) may be operable, without the SIM, but the mobile device **500** is unable to carry out functions involving communications over the network **519**, other than any legally required operations, such as '911' emergency calling.

After any required network registration or activation procedures have been completed, the mobile device **500** is able to send and receive communication signals, preferably including both voice and data signals, over the network **519**. Signals received by the antenna **516** from the communication network **519** are routed to the receiver **512**, which provides for signal amplification, frequency down conversion, filtering, channel selection, etc., and may also provide analog to digital conversion. Analog to digital conversion of the received signal allows more complex communication functions, such as digital demodulation and decoding, to be performed using the DSP **520**. In a similar manner, signals to be transmitted to the network **519** are processed, including modulation and encoding, for example, by the DSP **520** and are then provided to the transmitter **514** for digital to analog conversion, frequency up conversion, filtering, amplification and transmission to the communication network **519** via the antenna **518**. Although a single transceiver **511** is shown for both voice and data communications, in alternative embodiments, the mobile device **500** may include multiple distinct transceivers, such as a first transceiver for transmitting and receiving voice signals, and a second transceiver for transmitting and receiving data signals, or a first transceiver configured to operate within a first frequency band, and a second transceiver configured to operate within a second frequency band.

In addition to processing the communication signals, the DSP **520** also provides for receiver and transmitter control. For example, the gain levels applied to communication signals in the receiver **512** and transmitter **514** may be adaptively controlled through automatic gain control algorithms implemented in the DSP **520**. Other transceiver control algorithms could also be implemented in the DSP **520** in order to provide more sophisticated control of the transceiver **511**.

The microprocessor **538** preferably manages and controls the overall operation of the mobile device **500**. Many types of microprocessors or microcontrollers could be used here, or, alternatively, a single DSP **520** could be used to carry out the functions of the microprocessor **538**. Low-level communication functions, including at least data and voice communications, are performed through the DSP **520** in the transceiver **511**. High-level communication applications, including the voice communication application **524**A, and the data communication application **524**B are stored in the non-volatile memory **524** for execution by the microprocessor **538**. For example, the voice communication module **524**A may provide a high-level user interface operable to transmit and receive voice calls between the mobile device **500** and a plurality of other voice devices via the network **519**. Similarly, the data communication module **524**B may provide a high-level user interface operable for sending and receiving data, such as e-mail messages, files, organizer information, short text messages, etc., between the mobile device **500** and a plurality of other data devices via the network **519**.

The microprocessor **538** also interacts with other device subsystems, such as the display **522**, RAM **526**, auxiliary I/O devices **528**, serial port **530**, keyboard **532**, speaker **534**, microphone **536**, a short-range communications subsystem **540** and any other device subsystems generally designated as **542**. For example, the modules **524**A-N are executed by the microprocessor **538** and may provide a high-level interface between a user of the mobile device and the mobile device. This interface typically includes a graphical component provided through the display **522**, and an input/output component provided through the auxiliary I/O devices **528**, keyboard **532**, speaker **534**, or microphone **536**. Such interfaces are designated generally as UI **46** in FIG. **3**.

Some of the subsystems shown in FIG. **7** perform communication-related functions, whereas other subsystems may provide "resident" or on-device functions. Notably, some subsystems, such as keyboard **532** and display **522** may be used for both communication-related functions, such

as entering a text message for transmission over a data communication network, and device-resident functions such as a calculator or task list or other PDA type functions.

Operating system software used by the microprocessor **538** is preferably stored in a persistent store such as the non-volatile memory **524**. In addition to the operating system and communication modules **524**A-N, the non-volatile memory **524** may include a file system for storing data. The non-volatile memory **524** may also include data stores for owner information and owner control information. The operating system, specific device applications or modules, or parts thereof, may be temporarily loaded into a volatile store, such as RAM **526** for faster operation. Moreover, received communication signals may also be temporarily stored to RAM **526**, before permanently writing them to a file system located in the non-volatile memory **524**. The non-volatile memory **524** may be implemented, for example, with Flash memory, non-volatile RAM, or battery backed-up RAM.

An exemplary application module **524**N that may be loaded onto the mobile device **500** is a PIM application providing PDA functionality, such as calendar events, appointments, and task items. This module **524**N may also interact with the voice communication module **524**A for managing phone calls, voice mails, etc., and may also interact with the data communication module **524**B for managing e-mail communications and other data transmissions. Alternatively, all of the functionality of the voice communication module **524**A and the data communication module **524**B may be integrated into the PIM module.

The non-volatile memory **524** preferably provides a file system to facilitate storage of PIM data items on the device. The PIM application preferably includes the ability to send and receive data items, either by itself, or in conjunction with the voice and data communication modules **524**A, **524**B, via the wireless network **519**. The PIM data items are preferably seamlessly integrated, synchronized and updated, via the wireless network **519**, with a corresponding set of data items stored or associated with a host computer system, thereby creating a mirrored system for data items associated with a particular user.

The mobile device **500** is manually synchronized with a host system by placing the mobile device **500** in an interface cradle, which couples the serial port **530** of the mobile device **500** to a serial port of the host system. The serial port **530** may also be used to insert owner information and owner control information onto the mobile device **500** and to download other application modules **524**N for installation on the mobile device **500**. This wired download path may further be used to load an encryption key onto the mobile device **500** for use in secure communications, which is a more secure method than exchanging encryption information via the wireless network **519**.

Owner information, owner control information and additional application modules **524**N may be loaded onto the mobile device **500** through the network **519**, through an auxiliary I/O subsystem **528**, through the short-range communications subsystem **540**, or through any other suitable subsystem **542**, and installed by a user in the non-volatile memory **524** or RAM **526**. Such flexibility in application installation increases the functionality of the mobile device **500** and may provide enhanced on-device functions, communication-related functions, or both. For example, secure communication applications may enable electronic commerce functions and other such financial transactions to be performed using the mobile device **500**.

When the mobile-device **500** is operating in a data communication mode, a received signal, such as a text message or a web page download, will be processed by the transceiver **511** and provided to the microprocessor **538**, which preferably further processes the received signal for output to the display **522**, or, alternatively, to an auxiliary I/O device **528**. Owner information, owner control information, commands or requests related to owner information or owner control information, and software applications received by the transceiver **511** are processed as described above. A user of mobile device **500** may also compose data items, such as email messages, using the keyboard **532**, which is preferably a complete alphanumeric keyboard laid out in the QWERTY style, although other styles of complete alphanumeric keyboards such as the known DVORAK style may also be used. User input to the mobile device **500** is further enhanced with the plurality of auxiliary I/O devices **528**, which may include a thumbwheel input device, a touchpad, a variety of switches, a rocker input switch, etc. The composed data items input by the user are then transmitted over the communication network **519** via the transceiver **511**.

When the mobile device **500** is operating in a voice communication mode, the overall operation of the mobile device **500** is substantially similar to the data mode, except that received signals are output to the speaker **534** and voice signals for transmission are generated by a microphone **536**. In addition, the secure messaging techniques described above might not necessarily be applied to voice communications. Alternative voice or audio I/O devices, such as a voice message recording subsystem, may also be implemented on the mobile device **500**. Although voice or audio signal output is accomplished through the speaker **534**, the display **522** may also be used to provide an indication of the identity of a calling party, the duration of a voice call, or other voice call related information. For example, the microprocessor **538**, in conjunction with the voice communication module **524**A and the operating system software, may detect the caller identification information of an incoming voice call and display it on the display **522**.

A short-range communications subsystem **540** is also to be included in the mobile device **500**. For example, the subsystem **540** may include an infrared device and associated circuits and components, or a Bluetooth or 802.11 short-range wireless communication module to provide for communication with similarly-enabled systems and devices. Thus, owner information insertion, owner control information insertion, and application loading operations as described above may be enabled on the mobile device **500** via the serial port **530** or other short-range communications subsystem **540**.

It is to be understood that FIG. **7** represents an example of an electronic device in which owner control systems and methods described above may be implemented. Implementation of such systems and methods in other electronic devices having further, fewer, or different components than those shown in FIG. **7** would occur to one skilled in the art to which this application pertains and are therefore considered to be within the scope of the present application. For example, although a SIM card has not been explicitly shown in FIG. **7**, it should be appreciated that implementation of owner control systems and methods in electronic devices with SIM cards is contemplated. Since SIM cards currently incorporate a memory component, owner information, owner control information, or both, may be inserted onto a SIM card and used to maintain owner control of an electronic device when the SIM card is installed in the electronic device. In this case, a SIM card could be branded by

inserting owner information onto the SIM card, and owner control information could then be inserted onto the SIM card or an electronic device in which the SIM card is installed.

What is claimed:

1. A method of application control on an electronic device, the method comprising:

receiving, by the electronic device, owner information from an owner of the electronic device;

receiving, by the electronic device, owner control information that comprises:

a list of applications permitted for installation on the electronic device, and

permissions associated with each permitted application in the list of applications;

storing, by the electronic device, the owner control information in a protected data store to prevent alteration or deletion of the owner control information in response to authenticating the owner control information using the owner information;

receiving, by the electronic device, from an application operating on the electronic device, a request to access local memory on the electronic device;

determining whether the application is allowed to access the local memory in response to identifying a permission associated with the application in the owner control information; and

controlling application access to the local memory based upon the determining.

2. The method of claim **1**, wherein the request to access the local memory comprises a request to erase data from the local memory.

3. The method of claim **1**, wherein the request to access the local memory comprises a request to read data from the local memory.

4. The method of claim **1**, further comprising restricting modification of the owner control information after the owner control information has been stored in the protected data store.

5. The method of claim **1**, wherein the owner control information includes an authorization record and an application identifier for each of the applications, and the owner control information is provided by an external source through a wireless communication channel.

6. The method of claim **5**, wherein the authorization record related to determining whether access to the local memory is allowed is provided by an external computer that is used to enforce policies for operating electronic devices within an organization.

7. The method of claim **1**, wherein an update to the owner control information is provided by an external source for storage on the electronic device.

8. The method of claim **1**, wherein a plurality of authorization records associated with a plurality of application identifiers are stored on the electronic device, the method further comprising:

receiving requests to access the local memory from a plurality of applications operating on the electronic device;

determining whether access to the local memory is allowed to be performed by their respective applications based upon the stored authorization records and the application identifiers that are respectively associated with the plurality of applications; and

controlling access by the plurality of applications to local memory based upon whether access to the local memory is allowed.

9. The method of claim **8**, wherein a group containing two or more of the applications is associated with one of the authorization records.

10. A device, comprising:

a memory; and

a processor coupled with the memory and configured by instructions stored in the memory to:

receive owner information from an owner of the device;

receive owner control information that comprises:

a list of applications permitted for installation on the device, and

permissions associated with each permitted application in the list of applications;

store the owner control information in a protected data store to prevent alteration or deletion of the owner control information in response to authenticating the owner control information using the owner information;

receive, from an application operating on the electronic device, a request to access local memory on the electronic device;

determine whether the application is allowed to access the local memory in response to identifying a permission associated with the application in the owner control information; and

control application access to the local memory based upon the determining.

11. The device of claim **10**, wherein the request to access the local memory comprises a request to erase data from the local memory.

12. The device of claim **10**, wherein the request to access the local memory comprises a request to read data from the local memory.

13. The device of claim **10**, wherein the processor is further configured to restrict modification of the owner control information after the owner control information has been stored on the electronic device.

14. The device of claim **10**, wherein the owner control information includes an authorization record and an application identifier for each of the applications, and wherein the owner control information is provided by an external source through a wireless communication channel.

15. The device of claim **14**, wherein the authorization record related to determining whether access to the local memory is allowed is provided by an external computer that is used to enforce policies for operating electronic devices within an organization.

16. The device of claim **10**, wherein an update to the owner control information is provided by an external source for storage on the electronic device.

17. A non-transitory computer-readable medium with instructions stored thereon, wherein the instructions are executable by a processor to cause the processor to perform the operations of:

receiving owner information from an owner of an electronic device;

receiving owner control information that comprises:

a list of applications permitted for installation on the device, and

permissions associated with each permitted application in the list of applications;

storing the owner control information in a protected data store to prevent alteration or deletion of the owner control information in response to authenticating the owner control information using the owner information;

receiving, from an application operating on the electronic device, a request to access local memory on the electronic device;

determining whether the application is allowed to access the local memory in response to identifying a permission associated with the application in the owner control information; and

controlling application access to the local memory based upon the determining.

18. The non-transitory computer-readable medium of claim **17**, wherein the owner control information includes an authentication record and an identifier for each application allowed to be executed on the electronic device.

19. The non-transitory computer-readable medium of claim **17**, wherein the request to access the local memory comprises a request to erase data from the local memory.

20. The non-transitory computer-readable medium of claim **17**, wherein the request to access the local memory comprises a request to read data from the local memory.

* * * * *

EXHIBIT B

US008115731B2

(12) **United States Patent**
Varanda

(10) **Patent No.: US 8,115,731 B2**
(45) **Date of Patent: Feb. 14, 2012**

(54) **METHOD OF OPERATING A HANDHELD DEVICE FOR DIRECTIONAL INPUT**

(75) Inventor: **Marcelo Varanda**, Ottawa (CA)

(73) Assignee: **Research In Motion Limited**, Waterloo, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 872 days.

(21) Appl. No.: **11/240,501**

(22) Filed: **Oct. 3, 2005**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(60) Provisional application No. 60/303,865, filed on Jul. 9, 2001.

(51) **Int. Cl.**
G09G 5/00 (2006.01)

(52) **U.S. Cl.** **345/156**; 345/157

(58) **Field of Classification Search** 345/156–172; 200/61.52; 434/38; 250/231.12, 236; 356/154
See application file for complete search history.

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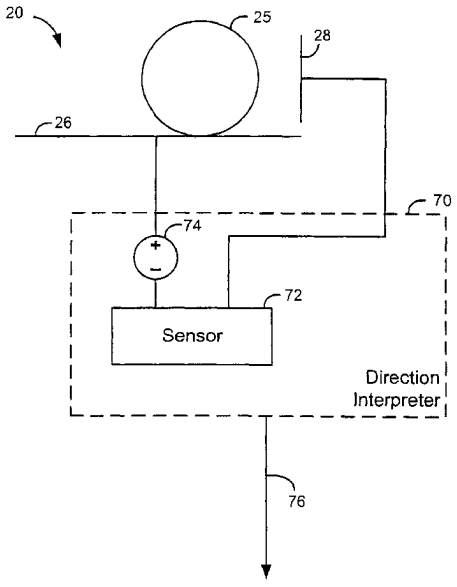
(57) **ABSTRACT**

A directional input device for use in a handheld device is disclosed herein. The directional input device provides input to an element of the user interface in response to the inclination of the handheld. The input device can be embedded into any handheld communicating or computing device to provide directional input to an element of the user interface of the handheld without consuming space on the face of the device that could otherwise be used for a larger screen.

15 Claims, 4 Drawing Sheets



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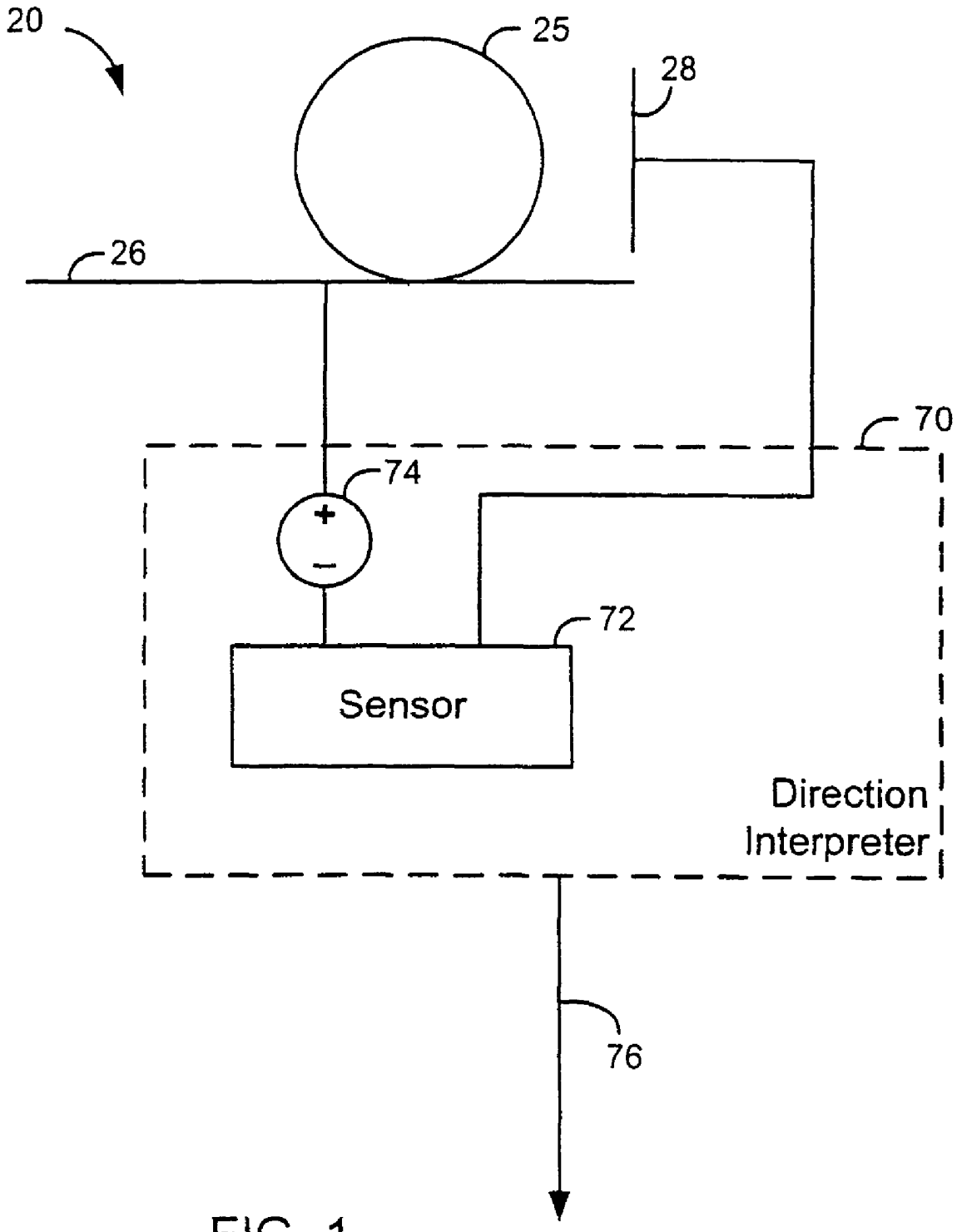

FIG. 1

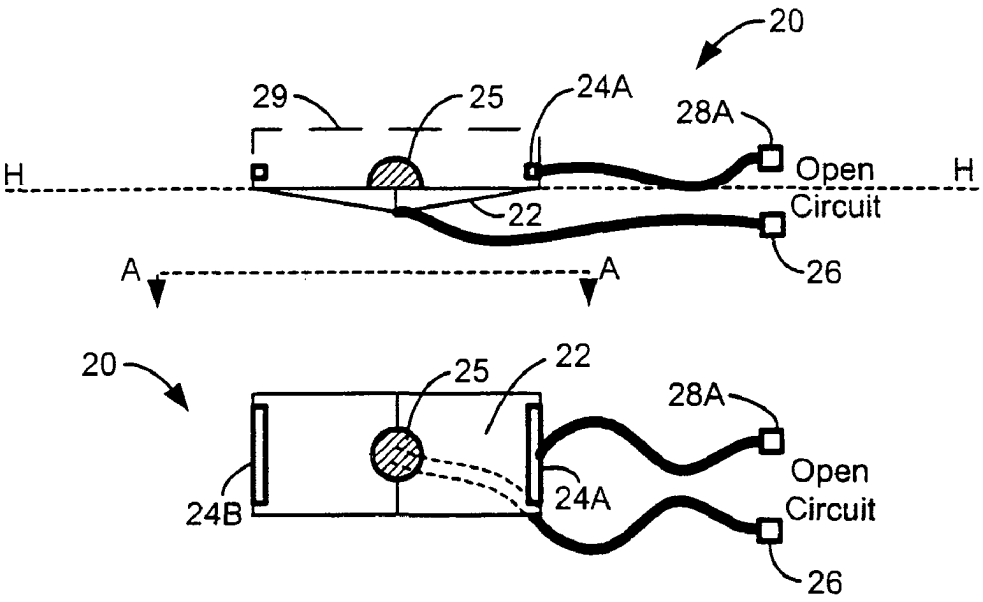
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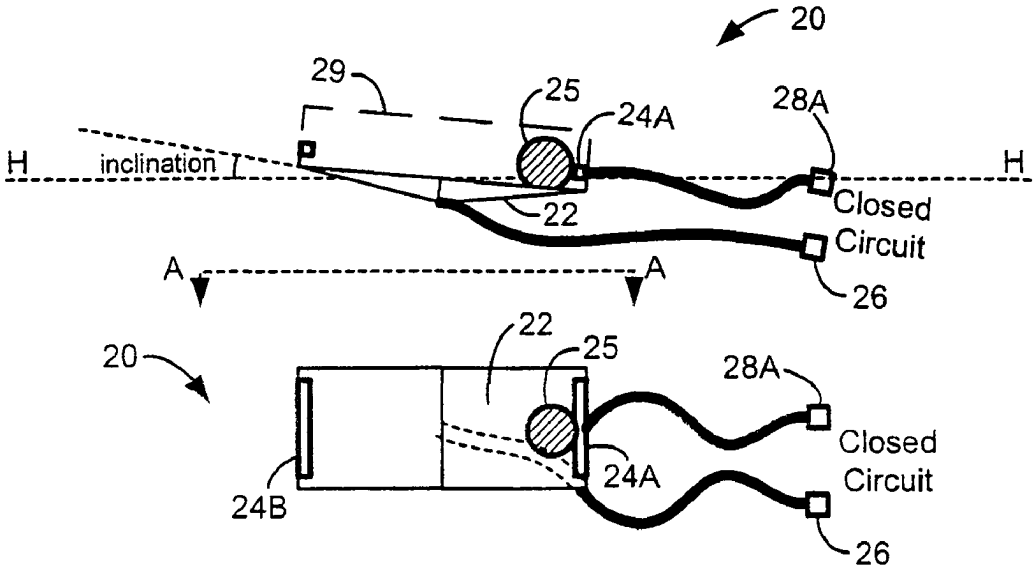
FIG. 2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Circuit
26

FIG. 3

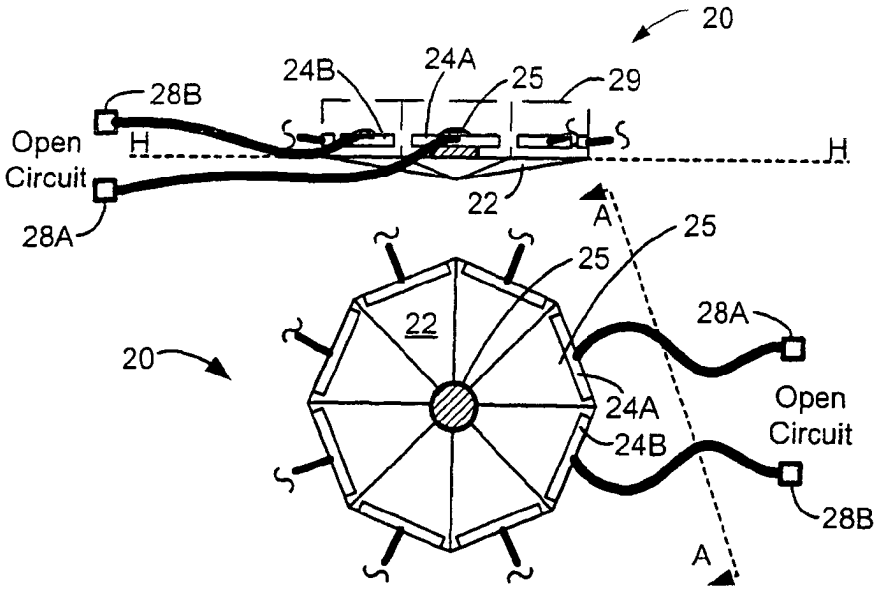
20
24B
24A
25
29
28B
Open
Circuit
H
H
22
28A
A
25
25
22
28A
20
24A
Open
Circuit
24B
28B
A

FIG. 4

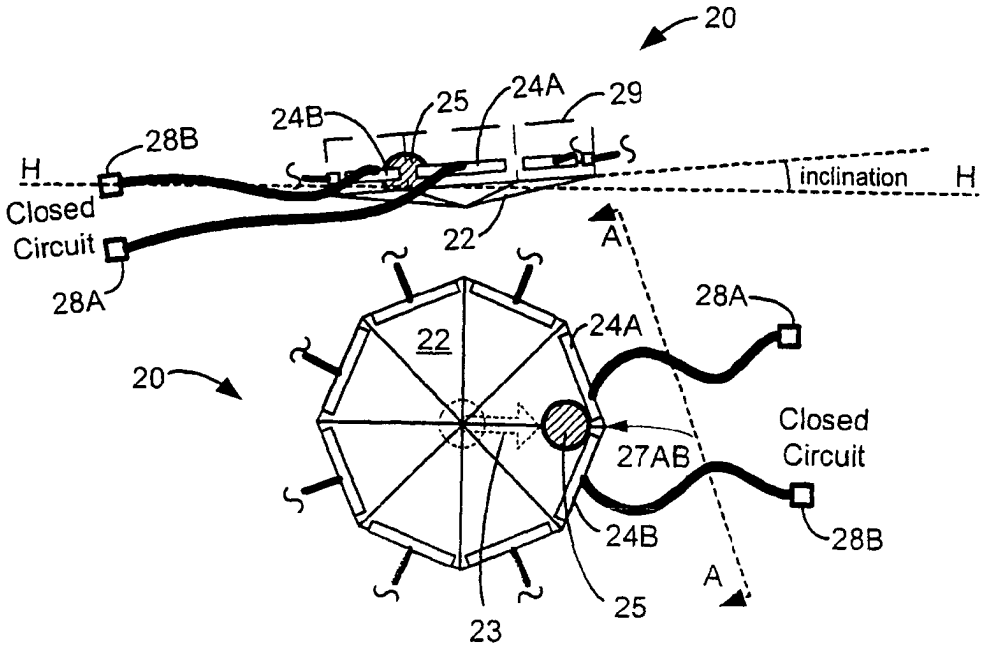
20
24B
25
24A
29
28B
H
inclination
H
Closed
Circuit
22
A
28A
22
24A
28A
20
Closed
Circuit
27AB
24B
28B
A
25
23

FIG. 5

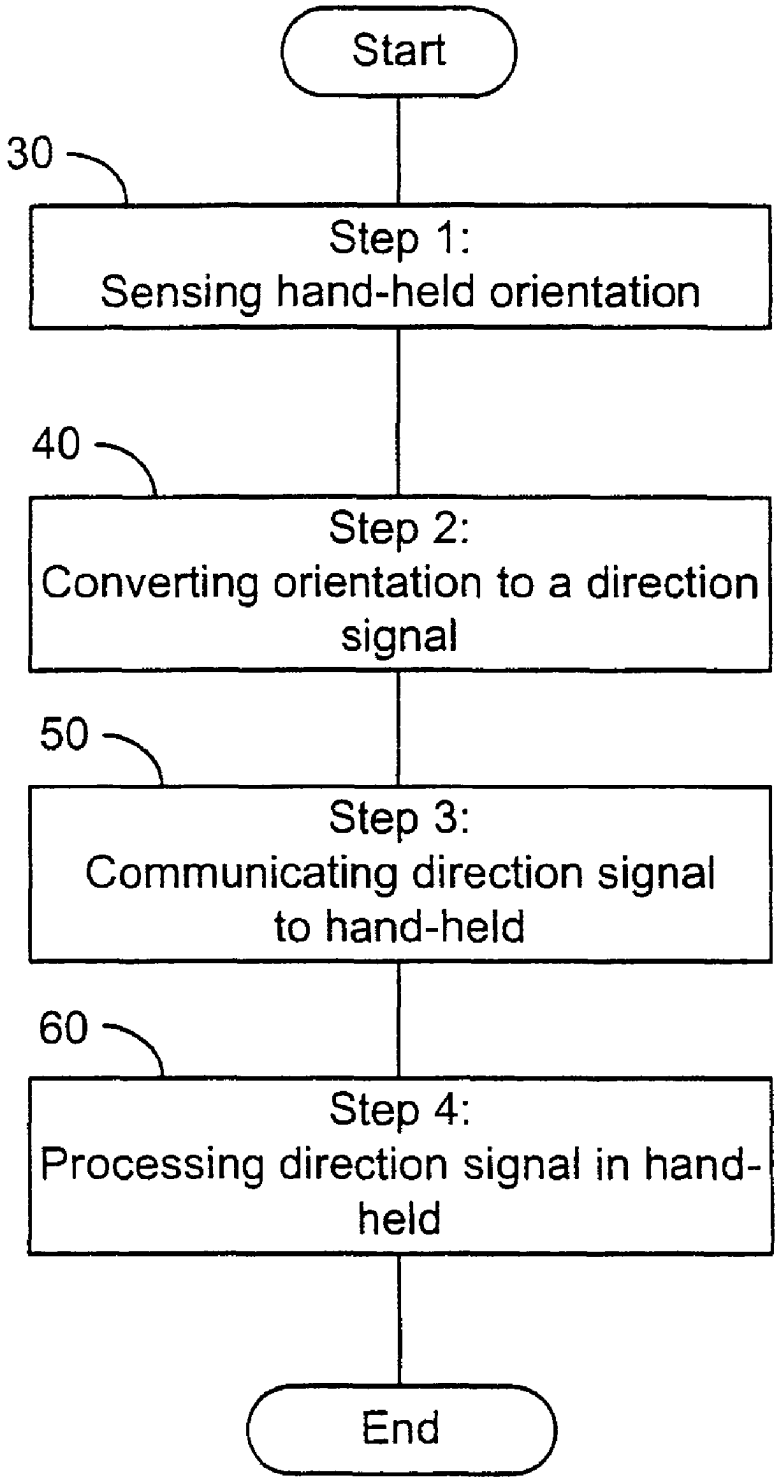
Start
30
Step 1:
Sensing hand-held orientation
40
Step 2:
Converting orientation to a direction signal
50
Step 3:
Communicating direction signal to hand-held
60
Step 4:
Processing direction signal in hand-held
End

FIG. 6

METHOD OF OPERATING A HANDHELD DEVICE FOR DIRECTIONAL INPUT

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional application from U.S. application Ser. No. 10/191,232 filed Jul. 9, 2002, now abandoned and further claims priority from U.S. Provisional Application Ser. No. 60/303,865, filed on Jul. 9, 2001. These applications, including the specifications and drawing figures, are hereby incorporated into this application by reference.

FIELD OF THE INVENTION

The present invention relates to the field of controlling a handheld device. More particularly, the present invention relates to a method of operating a handheld device for directional input, converting a pattern of physical parameters into signals processed by the handheld device.

BACKGROUND OF THE INVENTION

Handheld computing and communication devices are well known. Cellular telephones, personal digital assistants (PDAs), and small form factor computers all require input from a user in order to operate. Typically, these handheld device have a processor connected to a memory, a screen and a user input device. The screen typically provides either a text or graphical interface through which options or applications are selected. In many instances a selection is made by use of a directional input device, such as a touchpad, rollerball, directional keypad, or thumbwheel. These options allow the user to position a pointer or a cursor on the list application or option desired. These directional input devices allow a user to select options, launch applications, and move pointers or cursors. Typically the directional input device works in conjunction with some variety of action button, such as a mouse button, or an integrated selector as used in many thumbwheel devices.

Directional input devices produce signals which are further processed by the handheld device to represent a direction to an element of the handheld device user interface. For example, in operations involving the displacement of a cursor on a screen, a handheld device user presses, rolls, touches, or exerts pressure on some directional sensor. The pattern of the physical parameter is converted into signals processed by the handheld, and ultimately the cursor or a pointer moves.

Directional input devices can be classified as having either one, or a plurality of degrees of freedom. Devices that have one degree of freedom are restricted to providing directional input in one dimension, for instance up-down, or left-right, but not both. In input devices with a plurality of degrees of freedom, several directions are possible, for instance both up-down and left-right. In typical directional input devices, only two dimensions are tracked. Though there are devices for tracking three dimensional input, typically these devices are used in conjunction with very specialised user interfaces. The quality of directional signals depends on the attributes of the sensed pattern of physical parameters, which ultimately depend on the type of sensors. For instance, simple push-buttons or keys can only detect directional presence-either the key is pressed, or it is not. On the other hand, a roller or touch surface can detect directional degree.

The layout of the handheld device is determined by a number of ergonomic and aesthetic constraints. One of the greatest constraints is the overall size of the device, which for

reasons of portability is tightly constrained. As a result of their small form factors, handheld devices typically trade off a desirable large screen, for necessary input device space. Without enlarging the handheld device, a larger screen must come at the cost of a smaller input device. There exist a number of well-known, convenient directional input devices, such as computer mice, trackballs and touchpads, that address a number of concerns in directional input devices. However, these devices either require a great deal of space or cannot be easily integrated with a portable handheld device.

To accomplish the reduction in input device size, many people have attempted to eliminate a distinct directional input device. Some devices have eliminated the distinct directional input device by employing a touch sensitive screen. This allows the user to select an option or application directly on the screen. This however, typically requires at least a rudimentary directional input device to allow scrolling through pages. Additionally, it requires two-handed operation, which is not always possible, and should not be necessary to perform simple tasks with the handheld device.

Another strategy is to employ a thumbwheel, such as a jog-dial, which can be place on the side of the handheld. This removes the directional input device from the face of the device and can save considerable space. By combining the simplicity of a roller, with optimal placement for use with the thumb, a thumbwheel is provided on handheld devices for directional input. A thumb roll in a first direction is interpreted as a directional input corresponding to a positive displacement on a first primary direction, such as up, whereas a thumb roll in a second opposite displacement is interpreted as a directional input corresponding to a negative displacement along the same first direction. Furthermore, by detecting a presence condition, such as the user holding down an "alt" key, at the same time as a thumb roll, the thumb roll can be interpreted to provide a pointer or cursor displacement in a second direction. Thus a thumbwheel can be adapted to provide multidirectional input. An example of bi-directional input, a specific type of multidirectional input, is the displacement of a cursor in a text editor pane wherein one direction corresponds to the character position of the cursor and wherein the other direction corresponds to the line number of the cursor. Though thumbwheels address many concerns, the thumbwheel requires a rotatable key to be installed in the handheld, which is only on one side of the device. The positioning of the directional input device on the side of the device makes the device difficult to use for either right or left handed people. Additionally, because the handheld is of a standard size, the positioning of the thumbwheel can make the device difficult to use for people with large or small hands. Furthermore, the thumbwheel, as with any mechanical device, is subject to mechanical wear and failure, and additionally increases the cost of manufacturing the mould for the device's exterior due to the additional apertures required.

In classifying directional input devices it should be noted that directional input devices can have both presence and degree. The simplest directional input device has presence, such as for example in an arrangement of pressure sensors such as buttons, each of which is associated with a fixed increment in a particular direction, such as is the case for example with arrow keys. Either a key is pressed, or it is not. The user's input has presence in one particular direction and is sensed in this fashion and the handheld device is signalled accordingly.

More advanced directional input devices can provide directional degree. Directional degree is related to the magnitude of displacement along a physical degree of freedom of the sensor. For instance, in a roller sensor, the degree of roller

activity is proportional to the displacement of the roller and has the same sign as the direction of displacement. The degree of user activity in a direction is sensed in this fashion and the handheld device is signalled accordingly. Degree can be simulated in devices that can only provide presence through mechanisms such as key repeat rate, which provides a plurality of presence signals if the input device is activated for a sufficient amount of time. Some directional input devices have both presence and degree, such as a rollers or touch surfaces, that are combined with at least one button.

Directional input devices can also be categorized by the degrees of freedom that they provide. Directional input devices which have only one physical degree of freedom, such as thumbwheels, are typically used to provide directional input restricted to a single path. Directional input devices which have more than one degree of freedom are traditionally used in multidirectional input, such as for example a capacitive touch surface type sensor manipulated with the finger or a stylus. Directional input devices with several degrees of physical freedom tend to be more expensive and complex to operate than sensors with only one degree of freedom.

As described above, sensors with only one physical degree of freedom, a presence based control can be used to select alternate directions, which are typically perpendicular to the primary direction, thereby providing simulated multidirectional input. An example is the aforementioned a thumbwheel which moves a cursor in one dimension in a native state, but moves the cursor in a perpendicular direction when an "alt" key is depressed.

In the case of sensors with several degrees of freedom, presence can be used to constrain the directional input signals to a major direction, such as horizontal, vertical, or diagonal, thereby providing a simulated unidirectional input, which facilitates the drawing of a straight line on a freeform surface such as a touchpad. To achieve this, a user could use a touch surface to draw a diagonal line, and then hold an action key to constrain the line to the direction of the largest component, either horizontal or vertical.

Current techniques of directional input control of handhelds often combine varied sensor types and methods to provide varied forms of directional input, each of which presents some advantages but unfortunately also has drawbacks.

Added user operational complexity may be required for simulated uni-dimensional input on devices using traditional multidegree of freedom directional input devices. The same can be said for simulated multidimensional input using traditional single degree of freedom directional input devices. The mere combination of the two types of input devices, such as providing both a thumbwheel and a touch surface, overcomes many problems, but still requires the expensive tooling required to install a thumbwheel, and does not eliminate the valuable area required by the touchpad.

There is therefore a need for a directional input device with a minimized size, to allow for a larger screen, while reducing the tooling costs associated with apertures on the moulding of the handheld device. There is a further need for a directional device that is capable providing directional input to a handheld without requiring dual handed operation, and without providing a preference to right handed people, left handed people, or people with a particular size of hand.

SUMMARY OF THE INVENTION

It is an object of the present invention to obviate or mitigate at least one disadvantage of previous directional input devices in handheld computing or communicating devices.

In a first aspect, the present invention provides an input device, for embedding in a handheld device, for providing directional input to an element of the user interface in the handheld device in response to an inclination of the handheld device. The input device comprises a primary contact positionally fixed in the handheld, and a directional contact positionally fixed in the handheld and operatively connected to the primary contact. A circuit closing means, such as a ball bearing or a mercury contact, is movable on, and in electrical contact with, the primary contact. In response to inclination of the handheld device in the direction of the directional contact, the circuit closing means moves between a neutral position in which the primary contact and the directional contact form an open circuit, and an active position in which the primary contact and the directional contact form a closed circuit. A direction interpreter, operatively connected to the primary and directional contacts, generates the directional input to the element of the user interface when the closed circuit is formed. In a further embodiment, a second directional contact is positionally fixed in the handheld and operatively connected to the primary contact to form a second open circuit when the circuit closing means is in the neutral position. The second open circuit is closable by the circuit closing means, in response to inclination of the handheld device in the direction of the second directional contact by movement of the circuit closing means to a second active position. In this case, the direction interpreter generates a second directional input when the circuit closing means is in the second active position.

In another embodiment, the input device includes a plurality of subsequent directional contacts, positionally fixed in the handheld. Each subsequent directional contact is connected to the primary contact to create a plurality of subsequent open circuits. Each subsequent open circuit closable by the circuit closing means in response to an inclination of the handheld device in the direction of the associated subsequent directional contact by movement of the circuit closing means to a subsequent active position. This embodiment can be modified such that each of the directional contacts is further connected to adjacent directional contacts to create a plurality of secondary open circuits. Each of the plurality of secondary open circuits is closable by the circuit closing means in response to inclination of the handheld to a junction of adjacent directional contacts.

The input device of claim **1**, further including a base, electrically connected to the primary contact, for supporting the circuit closing means in response to movement between the neutral position and the active position.

In a further aspect, the present invention provides an input device, embedded in a handheld device, for providing directional input to an element of the user interface in the handheld device in response to an inclination of the handheld device. The input device comprises a base positionally fixed in the handheld. A plurality of directional contacts, positionally are fixed in the handheld around the base. Each directional contact is operatively connected to at least one adjacent directional contact. Circuit closing means, movable on the base between a neutral position and a plurality of active positions, is provided. In the neutral position the base and the plurality of directional contacts are in open circuit. In the active positions two of the plurality of directional contacts are operatively connected to close the open circuit in response to the inclination of the handheld device in the direction of a pair of adjacent directional contacts. A direction interpreter is operatively connected to the plurality of directional contacts, and generates the directional input in response to closing the open circuit. Preferably, the base biases the circuit closing means to

the neutral position, and is provided with a plurality of grooves for guiding the circuit closing means between the neutral position and at least one of the plurality of active positions.

In another aspect, there is provided a method of controlling an element of a user interface of a handheld device based on the inclination of the handheld device. The method comprises sensing the inclination of the handheld device; generating a directional input signal representative of the inclination of the handheld device; transmitting the generated directional input signal to the user interface of the handheld device; and processing the transmitted directional input signal to control the element of the user interface.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying Figs.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figs., wherein:

FIG. **1** illustrates an embodiment of a system of the present invention;

FIG. **2** illustrates top and side views of an embodiment of a 1 degree of freedom directional input device of the present invention in a neutral position;

FIG. **3** illustrates top and side views of an embodiment of a 1 degree of freedom directional input device of the present invention in an active position;

FIG. **4** illustrates top and side views of an embodiment of a 2 degree of freedom directional input device of the present invention in a neutral position;

FIG. **5** illustrates top and side views of an embodiment of a 2 degree of freedom directional input device of the present invention in an active position; and

FIG. **6** is a flowchart which illustrates the steps in one embodiment of the method of directional input for a handheld device in accordance with the present invention.

DETAILED DESCRIPTION

Generally, the present invention provides a directional input device integrated into a handheld device. In particular the present invention provides a directional input device that is internal to the handheld device, so that directional input is provided by manipulation of the orientation of the entire handheld device.

The present invention provides a directional input device that provides a directional input signal when the orientation of the handheld device is manipulated. For example, if it desired to move the cursor to the right, the handheld would be tilted to the right. This completely removes the directional input device from the face of the device to allow for a larger screen, and does not require either an external mechanical mechanism subject to external wear and tear or an expensive moulding modification.

FIG. **1** illustrates the principle of the present invention. Directional input device **20** is typically embedded in a handheld device. A base, or primary contact **26**, is connected to a directional contact **28**, to create an open circuit. Between primary contact **26** and directional contact **28** is a direction interpreter **70**. When a connection is made between primary contact **26** and directional contact **28**, direction interpreter **70** senses the closing of the open circuit and generates a directional input signal **76**. Circuit closing means **25** is provided, so that the open circuit can be closed by inclining the handheld. When the handheld device is inclined, directional input device **20** is inclined, which results in base **26** tilting, allowing gravity to pull circuit closing means **25** towards directional contact **28** which causes circuit closing means **25** to close the open circuit. As illustrated in FIG. **1**, circuit closing means **25** is in a neutral position, which corresponds to the open circuit remaining open. When the handheld device is sufficiently inclined, circuit closing means **25** moves to an active position, in which the open circuit is closed. One of skill in the art will appreciate that a number of different implementations of circuit closing means are available. Illustrated in FIG. **1** is a simple embodiment, where a ball bearing is used as the circuit closing means. Tilting the directional input device will cause the ball bearing to roll along primary contact **26** towards directional contact **28**. Upon touching contact **28**, the bearing will close the circuit. In an alternate embodiment, circuit closing means **25** is a small quantity of mercury that forms a mercury contact. The use of mercury as circuit closing means **25**, reduces the present invention to a mercury switch that is used to provide a directional input.

One of skill in the art will appreciate that a number of embodiments of direction interpreter **70** are possible. FIG. **1** illustrates a simple embodiment, wherein contacts **26** and **28** are connected by a power supply **74** and a sensor **72**. While contacts **26** and **28** are connected in an open circuit configuration no power flows between them, but when circuit closing means **25** moves to the active position the open circuit is closed and sensor **72** can detect the current flow between the contacts. One of skill in the art will appreciate that this is a simple embodiment of the direction interpreter **70**, and that further embodiments could be employed by one of skill in the art without departing from the scope of the present invention.

FIG. **2** illustrates the top and side views of an improved one degree of freedom directional input device according to the present invention. Though inclining the device of FIG. **1** results in the open circuit being closed, there is no guarantee that circuit closing means **25** will return to its neutral position when device **20** returns to a horizontal inclination. This is problematic for both applications of the present invention in which degree is simulated, and applications where both positive and negative directional control (e.g. both left and right inputs) is required. To overcome this, base **22** of device **20**, as illustrated in FIGS. **2** and **3**, is designed to bias circuit closing means **25** to the neutral position when the inclination is ceased. In the embodiment illustrated in FIGS. **2** and **3**, the base is curved so that gravity will pull the circuit closing means back to the neutral position, this gravitationally biases circuit closing means **25** to the neutral position. Base **22** is connected to lead **26**, which forms an open circuit with lead **28**A, which is connected to contact **24**A. One of skill in the art will readily appreciate that the open circuit between leads **26** and **28**A include direction interpreter such as direction interpreter **70** of FIG. **1**. The direction interpreter has been omitted for clarity of the drawings. Also omitted for clarity is a lead from connection **24**B that forms a second open circuit with lead **26**. As device **20** of FIGS. **2** and **3** is inclined in one direction or another, the circuit closing means **25** is pulled by gravity towards one of the contacts (contact **24**A as illustrated in FIG. **3**). The direction interpreter detects the closed circuit when circuit closing means **25** is in an active position and generates a directional input signal. Lid **29** serves to both contain the circuit closing means **25**, and to seal device **20**. The embodiment of FIGS. **2** and **3** provides a directional input device with a biased neutral position and two active positions, each active position being associated with the closure of one of the two open circuits.

One of skill in the art will readily appreciate that a two degree of freedom directional input device can be implemented using a simple extension of the above embodiment. Whereas the embodiment of FIGS. **2** and **3** restricts the path of circuit closing means **25** to a single dimension, in a 2-degree of freedom embodiment, circuit closing means **25** is allowed to move freely in two directions, and is bounded by a plurality of contacts arranged about the base so as to form an approximation of a circle. Each directional contact is connected to the base in the same fashion that contacts **24**A and **24**B were connected to base **22**, via lead **26**, to create an open circuit. When the handheld is tilted in any direction the directional input device **20** is inclined. This causes the circuit closing means **25** to create a closed circuit between one of the contacts and the base by gravitationally overcoming the bias to the neutral position. This can be sensed by a direction interpreter which would provide a directional input signal. One of skill in the art will readily appreciate that the circuit closing means will often close more than one circuit simultaneously by touching two adjacent directional contacts. The direction interpreter will recognise the multiple closed circuits as motion in a direction corresponding to a combination of the directions associated with each directional contact in the closed circuits.

FIGS. **4** and **5** illustrate another embodiment of the present invention. Referring to FIG. **4** a first embodiment of a two degree of freedom directional input device **20** is illustrated. The orientation sensor **20** is preferably embedded in a handheld device. FIG. **4** illustrates the present embodiment in the neutral position. A dish, or base, **22** supports circuit closing means **25** and biases circuit closing means **25** to the neutral position. As illustrated, base **22** is substantially horizontal with respect to line HH. A plurality of direction contacts **24**A, **24**B, and further unlabelled direction contacts, are disposed on the interior of a non-conductive cover **29** in a peripheral fashion, to form a circular approximation. Preferably, at an equilibrium orientation of the handheld device, the shape of base **22** biases the circuit closing means **25** to the neutral position.

Referring to FIG. **5**, an inclined or active position is illustrated. Base **22** is inclined past a certain threshold by inclining the handheld in the direction **23** of a pair of direction contacts **24**A,B. Circuit closing means moves along a guide **27**AB and comes to rest on the direction contacts **24**A,B thereby creating a closed circuit condition which can be sensed between the direction contact leads **28**A,B. This embodiment does not require a contact for the base **22**.

In reference to FIGS. **1-5**, various embodiments of orientation sensors are described. Although not expressly shown in the Figs., many alternative sensors are compatible with the method, such as a solid state compass or gyroscope which senses orientation with respect to magnetic north, or a pendulum such as a tine pendulum, a micro saucer, or a solid state memory device. The choice of an actual orientation sensor is a matter which depends on the application of the present invention to a particular handheld device and the choice of sensor is obvious to those knowledgeable in the field in light of a particular handheld and the present invention.

Although not expressly shown in the drawings, the use of a sensor that detects orientation in terms of degree instead of presence is also envisaged. Many orientation sensors can be used to detect degree using orientation, of varied complexity from as simple a principle as a pendulum, or a solid state compass, to as complex a principle as a gyroscope. The substitution of any orientation sensor is considered obvious to a person skilled in the art in view of this invention.

Finally, having described general principles of directional input, having considered examples of handheld devices, and having considered examples of orientation sensors in reference to FIGS. **1-5**, embodiments of the method for operating a handheld device for directional input will be described next by way of example and reference to FIG. **6**.

The method of FIG. **6** can be used to signal to an element of the user interface in the handheld that a change in orientation has occurred. Typically the element of the user interface is either a cursor or a pointer. In relation of the embodiments of the system as illustrated in FIGS. **1-5**, this signalling to the handheld occurs when the circuit closing means moves to an active position. The first step **30** of the method is to sense the handheld orientation or inclination. Once the handheld orientation has been sensed, the second step **40** is to convert the orientation to a direction signal. Then, at the third step **50** the direction signal is communicated to the handheld. Finally, at the fourth step **60** the direction signal is further processed in the handheld. In the fourth step, events are generated by the further processing of the signal, such as by detecting patterns of the signal which correspond to patterns of the physical parameters of the sensors can be as complex or as simple as required. For instance as accelerated directional input, to as simple as a simple click caused by the flick of the wrist, as defined by processing steps.

Although not expressly shown in the drawings, the second step **40** is not required if the sensed orientation is already converted to a direction signal by a direction interpreter. Adaptation of the present invention to use alternate orientation sensors is within the scope of the invention as it would be obvious to a person skilled in the art in view of this disclosure.

In one embodiment, orientation is used as the basis for directional input on a handheld device. Returning to FIG. **6**, in the second step **40**, the orientation is converted to a direction signal compatible with traditional directional input means, such as a roller, touch pad, or arrow keys, thereby allowing a next generation handheld using the method to reclaim the space used by traditional directional controls such as a thumbwheel.

In another embodiment, orientation is used in conjunction with other forms of directional input such as that provided by buttons, a roller, a touch surface or any other sensor capable of providing directional input, on a handheld device. For instance, a thumbwheel can be used to signal a degree of displacement in conjunction with the orientation sensed at the first step **30**. At step **40**, the sensed orientation and amount of roller displacement are converted into a direction signal.

In an axis constraining embodiment, a change in orientation constrains the axis corresponding to directional input on a handheld device. For instance, a touch pad on an handheld oriented so as to be inclined along an inclination axis is used to signal a degree of displacement in conjunction with the orientation sensed at the first step **30**. At step **40**, the sensed orientation and amount of touch pad displacement are converted into a direction signal constrained in a direction substantially perpendicular to the inclination axis.

In an axis selecting embodiment, the orientation is mapped to an axis corresponding to directional input on a handheld device. For instance, a touch pad on an handheld oriented so as to be inclined along an inclination axis is used to signal a degree of displacement in conjunction with the orientation sensed at the first step **30**. At step **40**, the sensed orientation and amount of touch pad displacement are converted into a direction signal constrained in a direction substantially parallel to the inclination axis. Alternatively, a sensed change of orientation sensed at step **30** can cause roller displacement to operate on an alternate direction at step **60**.

The present invention provides a directional input device that does not consume surface area on the face of a handheld device. This allows for a larger screen in the same form factor as a handheld device with a face mounted directional input device. Additionally, because it can be completely embedded in the handheld, no external access is required, obviating the need for expensive apertures in the moulding. Furthermore, reliability of the directional input device is improved by eliminating the mechanical wear that occurs with an externally accessible directional input device such as a thumbwheel.

The above-described embodiments of the present invention are intended to be examples only. Alterations, modifications and variations may be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

The invention claimed is:

1. A handheld computing device, comprising:

a display;

an internally located directional input device providing a directional input signal, the directional input signal corresponding to an axis of inclination of the handheld computing device and indicating an orientation;

a second directional input device providing a second directional input signal, the second directional input signal indicating an amount of displacement;

a processor coupled to the internally located directional input device and the second directional input device and operable to receive and process the directional input signal in conjunction with the second directional input signal; and

a memory subsystem, the memory storing an operating system executed by the processor to display on the display a graphical user interface for controlling the operation of the handheld computing device, wherein the graphical user interface provides a graphical element;

wherein the operating system comprises processor-executable instructions that cause the graphical element to move by the amount of displacement in a direction substantially parallel or substantially perpendicular to the orientation.

2. The handheld computing device of claim **1**, wherein the internally-located directional input device comprises:

a primary contact positionally fixed in the handheld computing device;

at least one directional contact positionally fixed in the handheld computing device and operatively connected to the primary contact;

circuit closing means, movable on, and in electrical contact with, the primary contact, the circuit closing means moving in response to inclination of the handheld computing device in the direction of any one of the at least one directional contact, between a neutral position in which the primary contact and the any one of the at least one directional contact form an open circuit, and an active position in which the primary contact and the any one of the at least one directional contact form a closed circuit; and

a direction interpreter, operatively connected to the primary contact and the at least one directional contact, for generating the directional input signal.

3. The handheld computing device of claim **2**, wherein the directional input signal is uniquely associated with the direction of the inclination.

4. The handheld computing device of claim **2**, wherein each of the at least one directional contact are further connected to adjacent directional contacts to create a plurality of secondary open circuits, each of the plurality of secondary open circuits closable by the circuit closing means in response to inclination of the handheld to a junction of adjacent directional contacts.

5. The handheld computing device of claim **4**, wherein the direction interpreter generates the directional input when one of the secondary open circuits is closed.

6. The handheld computing device of claim **2**, further including a base, electrically connected to the primary contact, for supporting the circuit closing means in response to movement between the neutral position and the active position.

7. The handheld computing device of claim **6**, wherein the base biases the circuit closing means to the neutral position.

8. The handheld computing device of claim **2**, wherein the circuit closing means is a ball bearing.

9. The handheld computing device of claim **2**, wherein the circuit closing means is a mercury contact.

10. The handheld computing device of claim **1**, wherein the graphical element is a pointer.

11. The handheld computing device of claim **1**, wherein the processor is configured to detect movement patterns from the directional input signal and wherein the graphical element is further responsive to the detected movement patterns.

12. The handheld computing device of claim **11**, wherein the graphical element is configured to accelerate in response to a detected movement pattern.

13. The handheld computing device of claim **11**, wherein the graphical element is configured to perform a selection function in response to the detected movement pattern.

14. The handheld computing device of claim **13**, wherein the detected movement pattern is a flick of the wrist.

15. The handheld computing device of claim **1**, wherein the second directional input device is selected from the group consisting of a button; a roller; a touch surface; and a thumbwheel.

* * * * *

EXHIBIT C

US008610397B2

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

(10) **Patent No.: US 8,610,397 B2**
(45) **Date of Patent: *Dec. 17, 2013**

(54) **BATTERY CHARGER FOR PORTABLE DEVICES AND RELATED METHODS**

(75) Inventors: **Michael L. Purdy**, Cambridge (CA); **Ryan Mitchell Bayne**, Waterloo (CA)

(73) Assignee: **BlackBerry Limited**, Waterloo, Ontario (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 46 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Jan. 24, 2012**

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US 2012/0119693 A1 May 17, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/978,902, filed on Dec. 27, 2010, now Pat. No. 8,120,313, which is a continuation of application No. 12/356,944, filed on Jan. 21, 2009, now Pat. No. 7,884,570, which is a continuation of application No. 11/763,214, filed on Jun. 14, 2007, now Pat. No. 7,489,102, which is a continuation of application No. 10/776,426, filed on Feb. 11, 2004, now Pat. No. 7,271,568.

(51) **Int. Cl.**
H02J 7/00 (2006.01)

(52) **U.S. Cl.**
USPC **320/106**; 320/132; 320/134

(58) **Field of Classification Search**
USPC 320/103, 106, 132, 134, 155–159, 320/162–164
See application file for complete search history.

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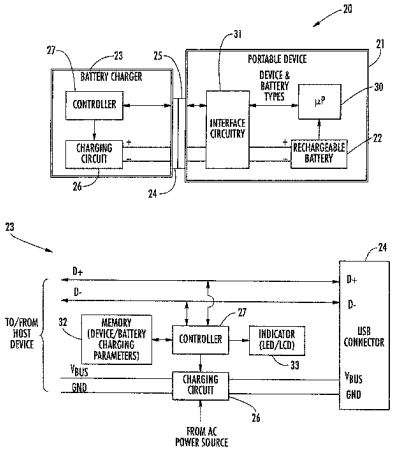
Primary Examiner — Richard V Muralidar
(74) *Attorney, Agent, or Firm* — Allen, Dyer, Doppelt, Milbrath & Gilchrist, P.A.

(57) **ABSTRACT**

A battery charger may include a charger connector to be coupled to a corresponding device connector of a portable device including a rechargeable battery. The battery charger may also include a charging circuit connected to the charger connector, and a controller connected to the charger connector and the charging circuit. The controller may be for causing a portable device connected to the charger connector to identify its corresponding portable device type and its corresponding rechargeable battery type from among a plurality of different portable device types and different battery types, and for causing the charging circuit to charge the rechargeable battery based thereon.

22 Claims, 5 Drawing Sheets



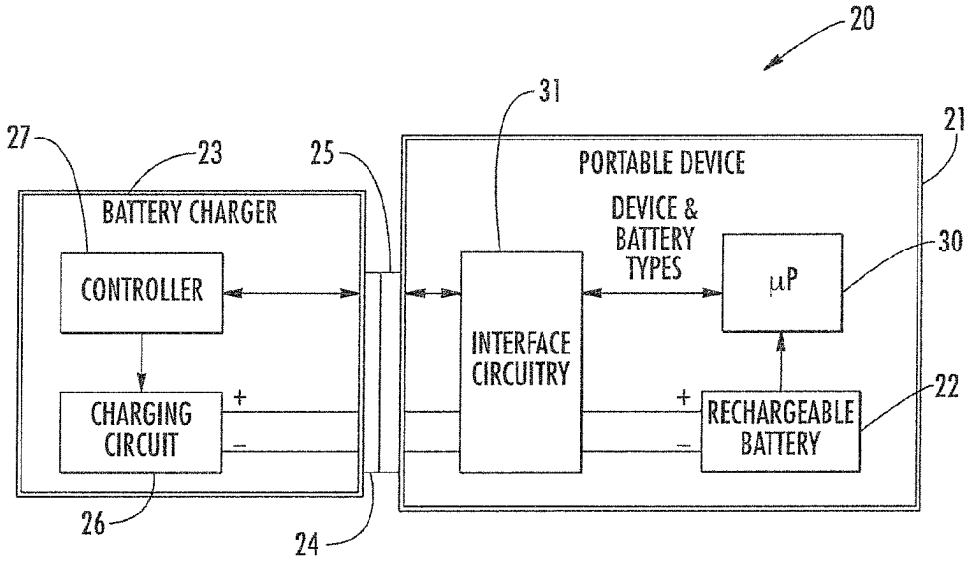

20
31
21
27
23
25
PORTABLE DEVICE
BATTERY CHARGER
DEVICE & BATTERY TYPES
30
CONTROLLER
μP
INTERFACE CIRCUITRY
CHARGING CIRCUIT
+
−
+
−
RECHARGEABLE BATTERY
22
26
24

FIG. 1

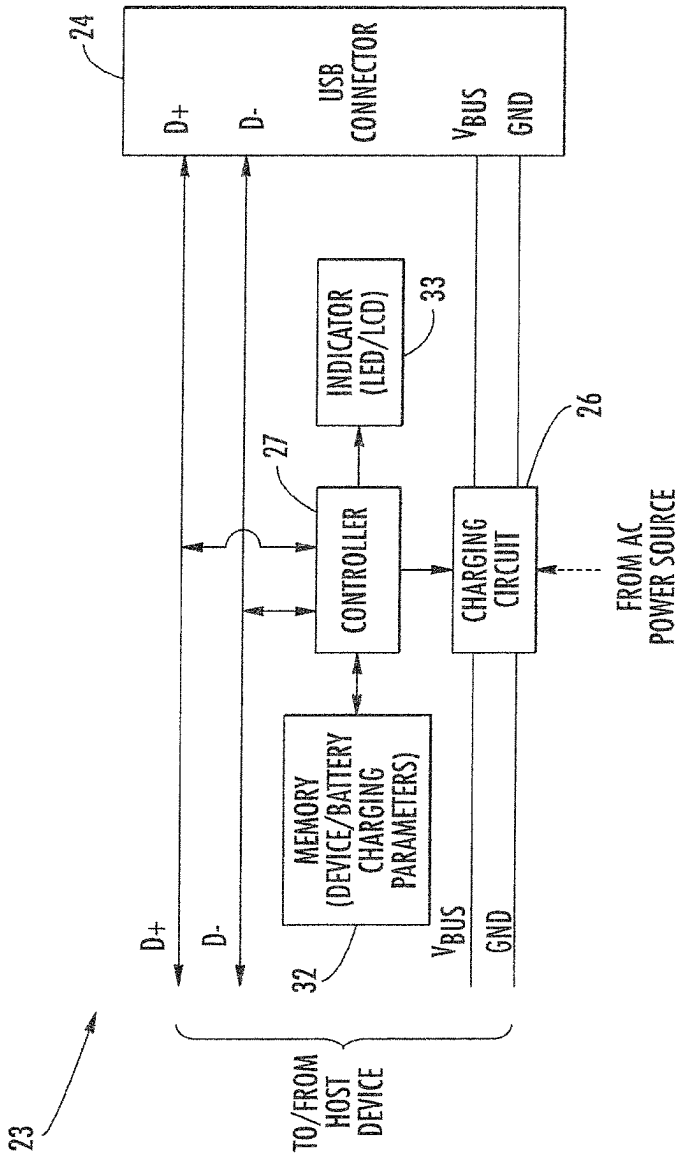

24
USB CONNECTOR
D+
D-
VBUS
GND
INDICATOR (LED/LCD)
33
27
26
CONTROLLER
CHARGING CIRCUIT
FROM AC POWER SOURCE
MEMORY (DEVICE/BATTERY CHARGING PARAMETERS)
32
D+
D-
VBUS
GND
TO/FROM HOST DEVICE
23

FIG. 2

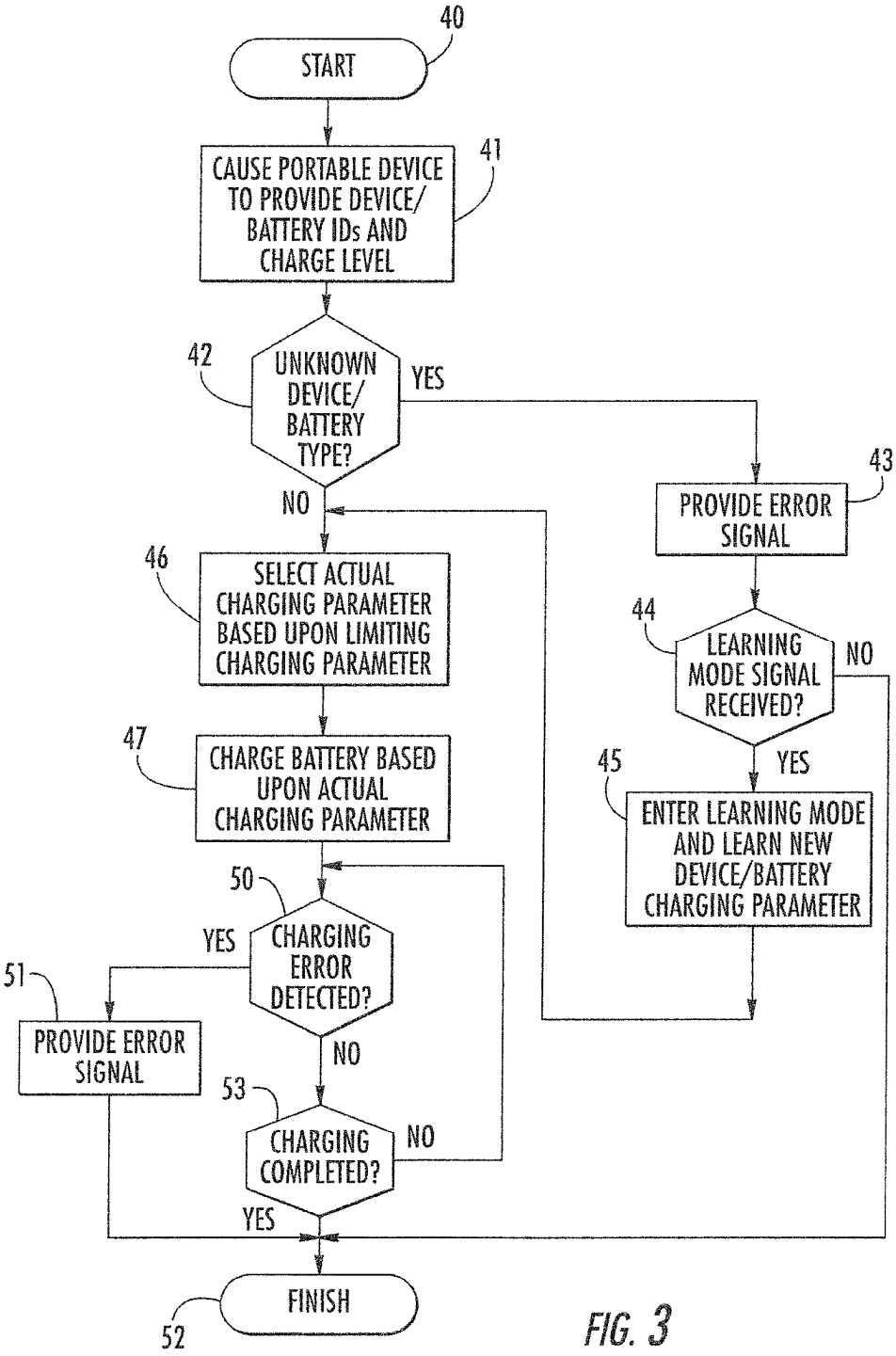

40
START
41
CAUSE PORTABLE DEVICE TO PROVIDE DEVICE/ BATTERY IDs AND CHARGE LEVEL
42
UNKNOWN DEVICE/ BATTERY TYPE?
YES
NO
43
PROVIDE ERROR SIGNAL
44
LEARNING MODE SIGNAL RECEIVED?
NO
YES
45
ENTER LEARNING MODE AND LEARN NEW DEVICE/BATTERY CHARGING PARAMETER
46
SELECT ACTUAL CHARGING PARAMETER BASED UPON LIMITING CHARGING PARAMETER
47
CHARGE BATTERY BASED UPON ACTUAL CHARGING PARAMETER
50
CHARGING ERROR DETECTED?
YES
NO
51
PROVIDE ERROR SIGNAL
53
CHARGING COMPLETED?
NO
YES
FINISH
52

FIG. 3

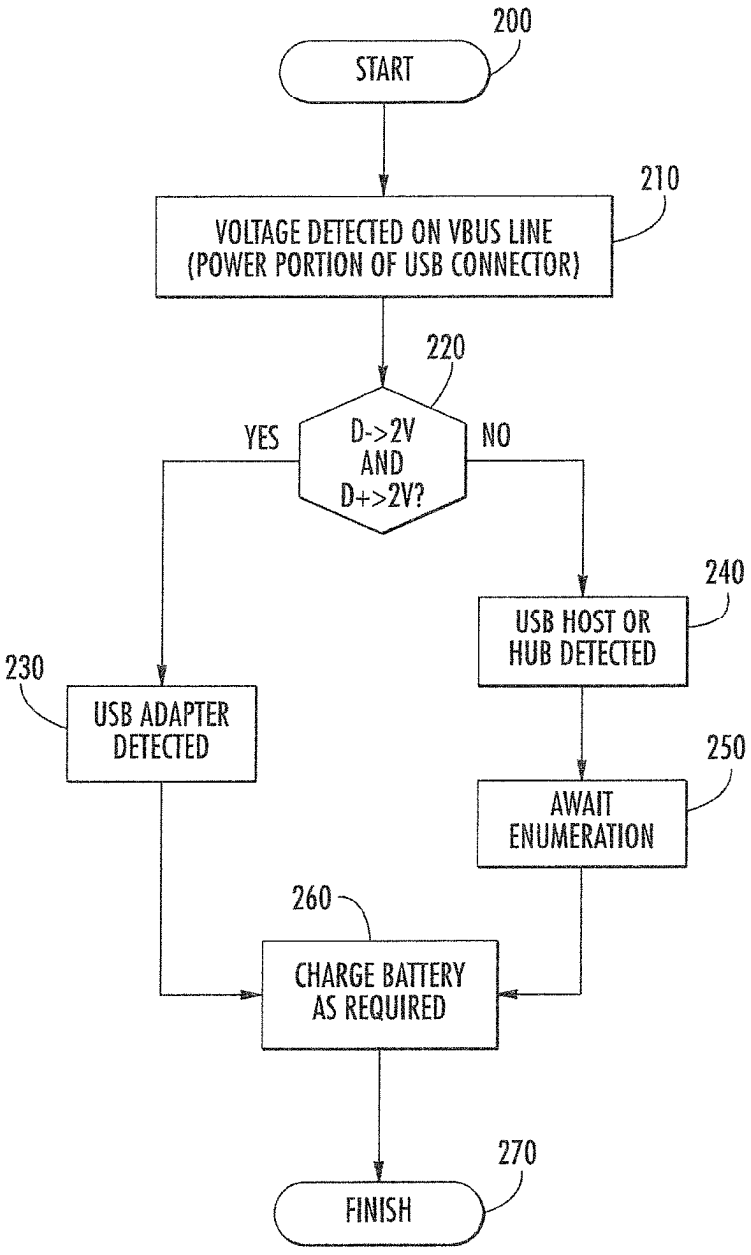

200
START
210
VOLTAGE DETECTED ON VBUS LINE (POWER PORTION OF USB CONNECTOR)
220
D->2V AND D+>2V?
YES
NO
230
USB ADAPTER DETECTED
240
USB HOST OR HUB DETECTED
250
AWAIT ENUMERATION
260
CHARGE BATTERY AS REQUIRED
270
FINISH

FIG. 4

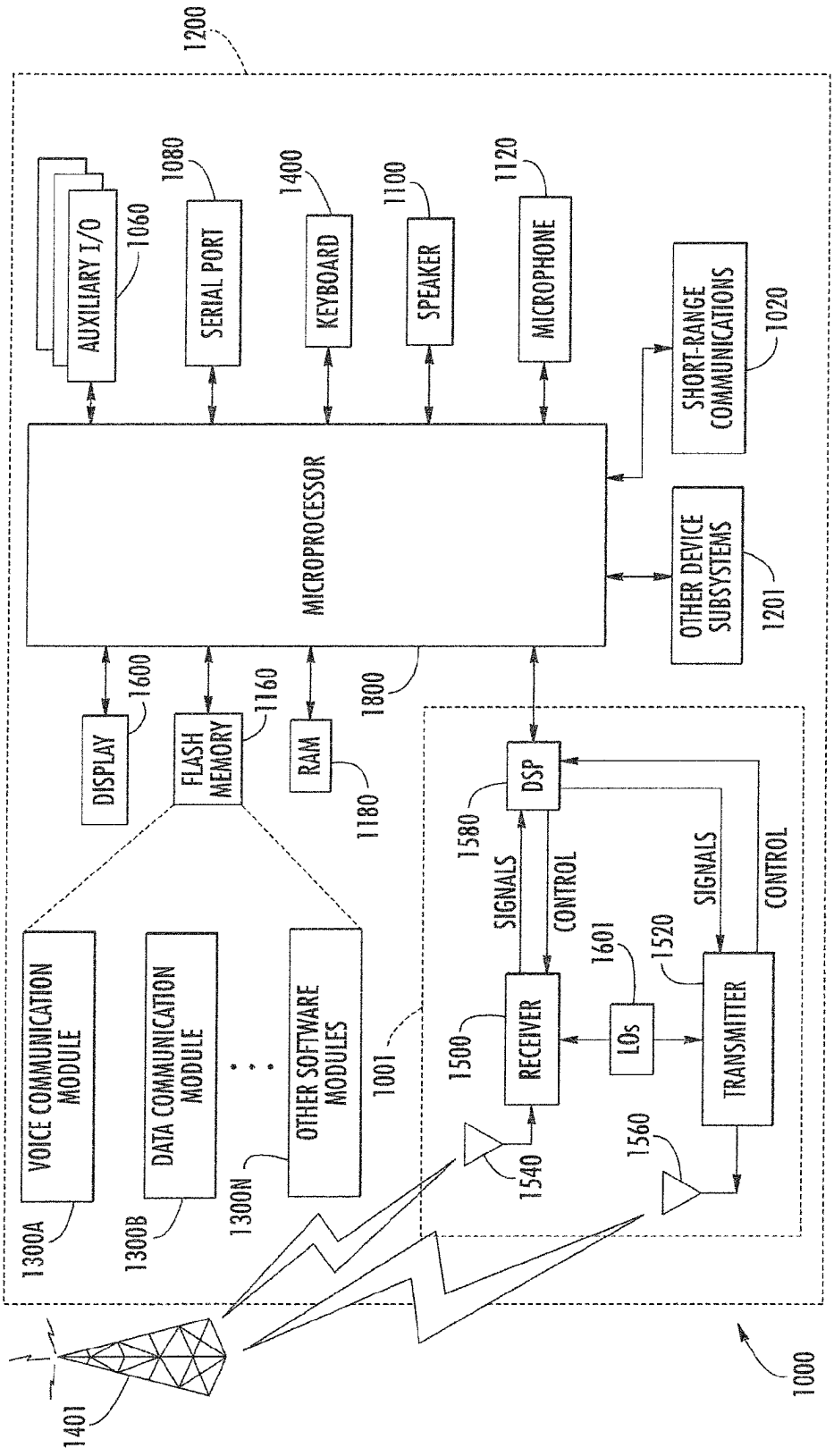

1200
AUXILIARY I/O
1060
SERIAL PORT
1080
KEYBOARD
1400
SPEAKER
1100
MICROPHONE
1120
SHORT-RANGE COMMUNICATIONS
1020
MICROPROCESSOR
OTHER DEVICE SUBSYSTEMS
1201
1800
DISPLAY
1600
FLASH MEMORY
1160
RAM
1180
DSP
1580
SIGNALS
CONTROL
SIGNALS
CONTROL
1601
1520
VOICE COMMUNICATION MODULE
DATA COMMUNICATION MODULE
OTHER SOFTWARE MODULES
1001
1500
RECEIVER
LOs
TRANSMITTER
1300A
1300B
1300N
1540
1560
1401
1000

FIG. 5

BATTERY CHARGER FOR PORTABLE DEVICES AND RELATED METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of Ser. No. 12/978,902 filed Dec. 27, 2010, now U.S. Pat. No. 8,120,313 issued Feb. 21, 2012, which, in turn, is a continuation of Ser. No. 12/356,944 filed Jan. 21, 2009 now U.S. Pat. No. 7,884,570 issued Feb. 8, 2011, which, in turn, is a continuation of Ser. No. 11/763,214 filed Jun. 14, 2007 now U.S. Pat. No. 7,489,102 issued Feb. 10, 2009, which, in turn, is a continuation of Ser. No. 10/776,426 filed Feb. 11, 2004 now U.S. Pat. No. 7,271,568 issued Sep. 18, 2007, all of which are hereby incorporated herein in their entireties by reference.

FIELD OF THE INVENTION

The present invention relates to the field of battery-powered portable devices, and, more particularly, to battery chargers for such portable devices and related methods.

BACKGROUND OF THE INVENTION

Rechargeable batteries are used in a wide variety of portable devices such as laptop computers, cellular telephones, personal digital assistants (PDAs), etc. With the rapid increase in portable device technology, it is fairly common for users to replace their portable devices at frequent intervals. However, users may be required to also purchase new battery chargers when upgrading portable devices, because of different connector types or battery types used for different portable devices.

In some cases, the use of standardized interfaces or connectors for portable devices allows a single battery charger to be used for charging different portable devices. For example, many portable devices now support the universal serial bus (USB) protocol, and include one or more USB connectors which allow them to be connected to personal computers (PCs), etc. Further details regarding the USB protocol and connectors may be found in the Universal Serial Bus Specification, Revision 2.0, Apr. 27, 2000, published by USB Implementers Forum, Inc., which is hereby incorporated herein in its entirety by reference. Thus, a charger having a USB connector could potentially be used to charge different portable USB devices.

An example of such a charger is disclosed in U.S. Pat. No. 6,184,652 to Yang. This patent is directed to a mobile phone battery charger with a USB interface that includes a USB compatible plug, a DC converter, and a mobile phone battery charging plug. The USB compatible plug is inserted into a corresponding USB connector of a computer and receives electrical power therefrom. The DC converter converts the electrical power into the necessary charging voltage, which is provided to the mobile phone by the battery charging plug. The battery charger may also detect the type of mobile phone battery (e.g., Li or Ni-MH) and the quantity of electricity or charge stored in the battery. The patent states that a user accordingly need not purchase different kinds of chargers for different battery types.

Another example is disclosed in U.S. Pat. No. 6,362,610 to Yang. More particularly, this patent discloses a universal USB power supply unit which includes a USB port connector and a charging connector. The USB port connector plugs into the jack of the USB port, while the charging connector plugs into the jack of an electronic product to be charged. The current flowing into the USB port connector will then pass through an automatic voltage regulator. Disposed within a housing of the automatic voltage regulator is a DC voltage transformer which transforms the DC voltage (e.g., 5 V) coming from the USB port to the requisite voltage supplied to a power/signal connecting jack. A feedback control voltage output circuit compares the feedback voltage signal of the power/signal connecting jack and enables the DC voltage transformer to output a preset voltage. The charging connector is fitted with a power cord which includes a power/signal connector to fit the power/signal connecting jack. Moreover, a voltage parameter associated with the particular electronic device is preset within the charging connector using a variable resistor.

Despite the advantages of such chargers, problems may still arise when different types of batteries are interchanged in different portable devices. That is, different rechargeable batteries may have different charging parameters (e.g., voltage rating, current rating, etc.). Yet, these parameters may not always match with those of a given portable device. Accordingly, using chargers such as those described above where the battery and device charging parameters are not carefully matched could result in damage to the device and/or battery.

SUMMARY OF THE INVENTION

In view of the foregoing background, it is therefore an object of the present invention to provide a battery charger that may be used with numerous types of portable devices and associated batteries, and yet which may account for differences between the charging parameters thereof.

This and other objects, features, and advantages in accordance with the present invention are provided by a battery charger which may include a charger connector to be coupled to a corresponding device connector of a portable device including a rechargeable battery. The portable device and rechargeable battery may each respectively have a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different battery types. The battery charger may also include a charging circuit connected to the charger connector, and a controller connected to the charger connector and the charging circuit. More particularly, the controller may be for causing a portable device connected to the charger connector to identify its corresponding portable device type and its corresponding rechargeable battery type, and cause the charging circuit to charge the rechargeable battery based thereon.

More particularly, different portable device types may have one or more different portable device charging parameters, and different battery types may similarly have one or more different battery charging parameters. For example, different types of batteries may have different voltage and/or current limits than one another, and different devices may similarly have different voltage and/or current limits as well. As such, the controller may advantageously select one or more actual charging parameters to charge the rechargeable battery based upon a comparison of the different portable device and battery charging parameters to avoid damaging one or the other.

By way of example, a particular rechargeable battery may have a higher voltage and/or current limit associated therewith than the portable device it is carried by. In such case, charging the battery at its highest rated voltage/current level could cause damage to the portable device. Accordingly, the controller may select the actual charging parameter(s) based upon a limiting one of the different portable device and battery charging parameters. Thus, the controller may prevent

the battery from being charged using a charging parameter that could damage either the portable device or the battery.

Moreover, the controller may also cause the portable device to identify a battery charge level of the rechargeable battery. Accordingly, the controller may further select the actual charging parameter(s) based upon the battery charge level. Thus, for example, the controller may select an actual charging parameter such as charging time based upon the charge level of the battery and a maximum charging time for the battery.

The battery charger may further include one or more memories connected to the controller for storing the different portable device/battery charging parameters. That is, the memory may store the appropriate device and battery charging parameters for each type of portable device and rechargeable battery to be used with the battery charger. Yet, to allow for use of the charger with future generations of portable devices and batteries, the controller may advantageously enter a learning mode for learning the at least one different portable device or battery charging parameter.

More specifically, the controller may enter the learning mode upon receiving a learning mode signal from the portable device. For example, if a portable device of an unknown device type, or which has an unknown battery type, is connected to the charger connector, the controller may provide an error signal to the portable device based thereon. The portable device may then provide the learning mode signal to the controller and communicate the appropriate charging parameter(s) thereto once the controller enters the learning mode. As such, the newly learned charging parameter(s) may advantageously be stored in the memory and used upon future connections of the device and/or battery type to the battery charger.

Additionally, the charger connector may also carry communications signals between the controller and a host device (e.g., a computer) connected thereto. More particularly, the communications signals may relate to at least one charging parameter. That is, the controller may advantageously learn charging parameters from the host device as well the portable device. Furthermore, in some embodiments the charger connector may also carry communications signals between the portable device and the host device. Thus, the battery charger may provide a docking station between the portable device and the host device. This arrangement may be particularly advantageous for portable devices such as personal digital assistants (PDAs) which not only have portable batteries, but which frequently are also used to synchronize calendar, contact, email, and other data with a computer.

The controller may also monitor the charging circuit to detect a charging error during charging of the rechargeable battery. By way of example, such charging errors may include over or undervoltage conditions, over or undercurrent conditions, excessive temperatures, exceeding a maximum charging time, etc. The battery charger may also include an indicator connected to the controller for providing an error indication upon detecting the charging error. For example, the error indicator could be an LED or LCD display. Also, the charger connector may be a universal serial bus (USB) connector, for example.

A battery charging system in accordance with the invention may include a portable device including a device connector and a rechargeable battery. The system may also include a battery charger for the portable device, such as the one described briefly above.

A battery charging method aspect of the invention for a rechargeable battery carried by a portable device may include coupling a device connector of the portable device to a corresponding charger connector, and connecting a charging circuit to the charger connector. The method may further include causing the portable device to identify its corresponding portable device type and its corresponding rechargeable battery type via the charger connector from among a plurality of different portable device types and different battery types, and causing the charging circuit to charge the rechargeable battery based thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is schematic block diagram of a battery charging system in accordance with the present invention.

FIG. **2** is a more detailed schematic block diagram of an embodiment of the battery charger illustrated in FIG. **1**.

FIG. **3** is a flow diagram illustrating a battery charging method in accordance with the present invention.

FIG. **4** is a flow diagram illustrating a method for identifying the battery charger to the portable device of FIG. **1**.

FIG. **5** is a schematic block diagram of an exemplary portable device for use with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Referring initially to FIG. **1**, a battery charging system **20** includes a portable device **21** including a rechargeable battery **22** carried thereby, and a battery charger **23** for charging the rechargeable battery. An exemplary portable device suitable for use with the present invention is described in the example below with reference to FIG. **5**. The charger **23** illustratively includes a charger connector **24** to be coupled to a corresponding device connector **25** of the portable device **21**. The battery, charger **23** also illustratively includes a charging circuit **26** connected to the charger connector **24**, and a controller **27** connected to the charger connector and the charging circuit.

By way of example, the portable device **21** could be any one of a laptop computer, personal digital assistant (FDA), mobile telephone, or other portable device having a rechargeable battery. More particularly, the battery charger **23** may advantageously be used with numerous types of portable devices and rechargeable batteries as well, as will be described further below. Generally speaking, the portable device **21** will include control circuitry for performing its various device functions, such as the microprocessor **30**. Moreover, many portable devices also include interface circuitry **31** for interfacing the microprocessor **21** with a data bus or cable, for example, that connects the portable device with a host device (e.g., a computer).

By way of example, the portable device **21** may be a USB compatible device, and the device connector **25** a USB connector. In this case, the interface circuitry **31** may perform a variety of operations such as connecting high or low logic signals to the differential data lines D+ and D− during enumeration with a host device, as will be appreciated by those skilled in the art. Moreover, the interface circuitry **31** may

also perform signal buffering as well as signal translation for converting differential signals to data signals recognizable by the microprocessor **30**, and vice-versa. The interface circuitry **31** may also connect the USB voltage references V_{BUS} and GND from the host device to the appropriate components in, the portable device **21** (e.g., the rechargeable battery **22** when the portable device is in a charging mode). As will be readily appreciated by those skilled in the art, different interface and control circuitry configurations may be used for the portable device **21** depending upon the given application.

For clarity of understanding, the present discussion will refer to the case in which the battery charger **23** is for charging portable devices which operate in accordance with the USB protocol and thus include a USB connector **25**, as described above. However, it will be understood by those of skill in the art that the battery charger **23** may be used with numerous types of devices and operational protocols, such as those using serial or parallel communications interfaces, etc. Moreover, it should also be noted that in some embodiments the battery charger **23** may include multiple connectors **24** for different types of device connectors **25**. Thus, for example, the battery charger **23** could be used to charge both USB devices and those which communicate using a serial (or other) communications interface.

An exemplary embodiment of the battery charger **23** for USB devices and operation thereof will now be described with reference to FIGS. **2** and **3**. More particularly, beginning at Block **40**, upon connection of the device connector **25** to the charger connector **24**, the controller **27** causes the portable device **21** (i.e., the microprocessor **30**) to identify its corresponding portable device type and its corresponding rechargeable battery type from among a plurality of different portable device types and different battery types, at Block **41**. The device type may be stored as a device identification (ID) in a non-volatile memory of the portable device **21** (e.g., an EEPROM), and the battery type may be identified by the microprocessor **30** from an identification circuit carried by the battery **22**, for example.

It should be noted that device and battery "types" may vary depending upon a given implementation of the present invention. For example, in some applications, device/battery types may be respective models of portable devices/batteries. However, in other applications, the device/battery types may correspond to a particular series of portable devices/batteries. For example, a manufacturer may make one base portable device but put different connectors thereon for different applications. As such, the base device may have the same charging parameters, but it will be assigned a different model number within a series (e.g., the 6000 series) depending upon the particular connector used therewith. Thus, in such cases the device type would include all of the devices within the given series. Similarly, device/battery type could also correspond to the manufacturer thereof in other applications (i.e., all devices by a particular manufacturer are of the same device type).

Various approaches may be used for causing the portable device **21** to identify its battery and device types. One particularly advantageous approach for USB compatible devices is for the controller **27** to initially place a logic high signal on both of the differential D+ and D− data lines when the connectors **24**, **25** are first connected. This is an otherwise invalid USB enumeration state, but for an appropriately configured portable device **21** this would indicate that the device has been connected to the battery charger **23**. As such, the portable device **21** may then suspend the normal USB enumeration operations it would otherwise use if connecting to a host device, for example, and instead enter a charging mode.

An exemplary implementation of this approach will now be described in greater detail. When the battery charger **23** is connected to the portable device **21**, the controller **27** preferably provides an identification signal to the portable device to notify the portable device that it is connected to a power source that is not subject to the power limits imposed by the USB specification. Preferably, the portable device **21** is programmed to recognize the identification signal, and it therefore recognizes that an identification signal has been transmitted by the controller **27**. After recognizing a valid identification signal, the portable device **21** is then ready to draw power from the charger **23** without performing USB enumeration.

The detection of the identification signal may be accomplished using a variety of methods. For example, the microprocessor **30** may detect the identification signal by detecting the presence of an abnormal data line condition at the USB port **25**, for example. As noted above, one exemplary identification signal results from the application of voltage signals greater than two volts to both the D+ and D− lines by the controller **27**. The foregoing will be further understood with reference to FIG. **4**.

Beginning at Block **220**, the portable device **21** detects the presence of a voltage on the Vbus line of the USB connector **25**, at Block **210**. The mobile device **21** then checks the state of the D+ and D− lines, at Block **220**. The D+ and D− lines are compared to a 2V reference, for example. The controller **27** of the charger **23** may apply a logic high signal, such as +5V reference, to both the D+ and D− lines. If the voltages on both the D+ and D− lines are greater than 2V, then the portable device **21** determines that it is not connected to a typical USB host or hub, and that the charger **23** has instead been detected (Block **230**). The portable device **21** is then ready to charge the battery or otherwise use power provided via the Vbus and Gnd lines (Block **260**) without waiting for enumeration, and without being limited by the power restrictions imposed by the USB specification, as will be appreciated by those skilled in the art.

It should be noted that the charger **23** may also serve as an interface to a host device or hub (e.g., a personal computer (PC)) as well as a charging station in some embodiments. In this case, the portable device **21** may still go through the enumeration process. More particularly, if the portable device **21** detects the presence of a voltage on the Vbus line (meaning the charger **23** is connected to the host device) and also determines that the voltages on both the D+ and D− lines are not greater than 2V (Block **220**), then the portable device determines that a USB host or hub has been detected (Block **240**). A typical USB host or hub weakly holds its D+ and D− lines at zero volts when it is not connected to another device. The portable device **21** may then signal the USB host or hub to initiate the enumeration process (Block **250**) and can use power provided via the Vbus and Gnd lines (Block **260**) in accordance with the power limits imposed by the USB specification and/or communicate with the host device, thus concluding the illustrated method (Block **270**).

Of course, battery charging could also be performed at this point, but it would be subject to the power restrictions imposed by the USB specification, as will be appreciated by those of skill in the art. The enumeration process is typically initiated after the portable device **21** applies approximately zero volts to the D− line and approximately 5V to the D+ line to inform the host of the portable device's presence and communication speed, as will also be appreciated by those skilled in the art. It should be noted that if no USB host is present, the portable device **21** may disable its typical USB functions in some embodiments, if desired.

Different portable device types will typically have one or more different portable device charging parameters, and different battery types may similarly have one or more different battery charging parameters. Table 1 provides exemplary charging parameters for two different types of USB compatible PDAs, while Table 2 provides exemplary charging parameters for two different types of PDA batteries.

TABLE 1

Exemplary Device Charging Parameters

Device Charging Parameter	Device Type #1	Device Type #2
Overvoltage limit (V)	6.0	5.25
Undervoltage limit (V)	4.0	4.8
Overcurrent limit (mA)	800	400
Constant current (mA)	750	350
Battery full (mA)	40	20
Battery full (V)	4.15	4.22

TABLE 2

Exemplary Battery Charging Parameters

Battery Charging Parameter	Battery Type #1	Battery Type #2
Max. Charge time (Hours)	4.0	8.0
Battery Capacity (mAh)	1000	2000

As may be seen from the tables, device type #1 can tolerate voltages as high as 6.0 V or as low as 4.0 V. That is, voltages outside this range could potentially damage the interface circuitry **31**, as well as other components of the portable device **21**, for example. Yet, device type #2 could be damaged by voltages outside of the range from 4.8 to 5.25 V. There is also a significant overcurrent limit disparity between device types #1 and #2 (i.e., 800 mA vs. 400 mA).

Accordingly, a charger set up to charge a portable device of type #1 could cause significant damage to a portable device of type #2 by applying a current/voltage outside of the above-noted ranges. For example, exceeding the maximum battery charge current could cause damage to the battery. This may be particularly problematic where both portable device types use the same type of device connector (e.g., a USB connector). That is, a user may assume that because the device connecter matches that of the charger it is safe to use the charger, which may not be true.

Moreover, even if a charger detects the appropriate voltage level for charging a particular battery, as with the prior art discussed above, a particular battery may support voltage or current levels inside the acceptable ranges for device type #1, but outside those for device type #2, for example. Thus, while the same battery type may fit in both device types and have a suitable operating voltage for both, charging the battery at or near its maximum charge limits could exceed the acceptable range for device type #2, as will be appreciated by those skilled in the art. Of course, the opposite is also true, namely that a given portable device could support charging parameters that could damage a particular battery type.

The battery charger **23** illustratively includes one or more memories **32** connected to the controller **27** for storing different portable device/battery charging parameters. That is, the memory **32** stores the appropriate device and battery charging parameters for each type of portable device and rechargeable battery **22** to be used with the battery charger **23**, which may be stored based upon respective device and battery IDs. By way of example, different sets of charging parameters may be stored in the memory during manufacture of the charger **23** for each device/battery type to be used with the charger. To this end, the memory **32** may be an EEPROM, for example, which would also advantageously allow for new charging parameters to later be stored therein, as will be discussed further below. Of course, other non-volatile (or even volatile) memories could be used as well.

The charger **23** checks to see whether the device and battery types are known based upon the device and battery IDs returned by the portable device, at Block **42**. If so, the controller provides an error signal to the portable device **21**, at Block **43**, letting it know that it (or the battery **22**) is unknown and that cannot therefore cannot be performed.

In some embodiments, the battery charger **23** may further include an indicator **33** connected to the controller **27**, which may be used for providing an error indication upon detection of an unknown device/battery type. Of course, if the portable device **23** includes its own indicator or display (e.g., a laptop, PDA, cell phone, etc.), such an error indication may instead (or in addition) be provided by the device indicator (not shown). By way of example, the indicator **33** may be an LED or LCD indicator, although other suitable indicators could also be used, such as audible indicators.

Even if a device or battery type is unknown to the controller **27**, it may advantageously learn or download the appropriate charging parameters for the device/battery. This allows the charger **23** to be used with future generations or models of devices/batteries that are not available when the battery charger **23** is manufactured, for example.

More specifically, the controller **27** may enter a learning mode for learning the new device/battery parameters upon receiving a learning mode signal from the portable device **21**, at Block **44**. For example, the portable device **21** may store its own charging parameters and, responsive to receiving an unknown device error signal from the controller **27**, send a designated learning mode signal that the battery charger **23** will recognize as such. The charging parameters for the rechargeable battery **22** may be stored in its identification circuit, for example.

Once the controller **27** enters the learning mode, the microprocessor **30** of the portable device **21** then communicates the appropriate charging parameters to the controller, which it then stores in the memory **32**, at Block **45**. The newly learned charging parameters are then available for use in charging the device and/or battery type, and these device types will be recognized by the controller **27** thereafter. If a learning mode signal is not received, the battery charger **23** will stop the charging process (Block **52**).

If the device and battery types are recognized by the controller **27**, it then selects actual charging parameters for charging the rechargeable battery **22** based upon a comparison of the different charging parameters for the portable device **21** and battery **22**, at Block **46**. More particularly, the controller **27** may select the actual charging parameters based upon a limiting one (or ones) of the different portable device an battery charging parameters, at Block **46**.

Using the above exemplary charging parameters from Tables 1 and 2, for example, if a device of type #2 with a battery of type #1 is being charged, the controller **27** may limit the charging time to four hours, even if the battery voltage has not reached the maximum charge level of 4.22 V for the device. Similarly, the controller **27** may also limit the charging current to 400 mA or charging voltage to within the 4.8-5.25 V range, even though the battery type may support other values. Various other selections of limiting charging

parameters are possible, as will be readily apparent to those of skill in the art based upon the examples provided herein.

Once the actual charging parameters are established, the charger **23** then causes the charging circuit **26** to charge the battery **22** in accordance with these actual charging parameters, at Block **47**. The charging circuit **26** may include a power supply or transformer for converting power from either an AC or DC source to the appropriate charging voltage based upon the actual charging parameters. Of course, the charging circuit **26** need not include a power supply/transformer in all embodiments. For example, in some applications the charging circuit **26** may receive power (i.e., 5 V) from the host device via the V_{BUS} line. Moreover, the power supply may be carried in a different housing than the controller **27**, for example, such as in the case of a wall plug transformer. Various configurations of the charging circuitry **26** will be readily apparent to those skilled in the art based upon a given application.

The controller **27** may also cause the portable device **21** to identify a battery charge level of the battery **22** and use this information in establishing the actual charging parameters. For example, the battery charge level may be communicated to the controller **27** by the microprocessor **30** along with the portable device and battery types (Block **41**). The battery charge level may also be sent to the controller **27** during charging, if desired, to help determine when the battery **22** has reached its full charge. This could be done automatically by the microprocessor **30** at predetermined intervals, or upon request by the controller **27**, for example. The controller **27** may also determine when the battery **22** has been fully charged based upon a charging parameter, e.g., a steady state current value which indicates when a battery has been completely charged, for example.

In addition, the controller **27** may also monitor the charging circuit **26** to detect a charging error during charging of the battery **22**, at Block **50**. By way of example, such charging errors may include over or undervoltage conditions, over or undercurrent conditions, excessive temperatures, etc. Upon detecting such an error, the controller **27** may provide an error indication via the indicator **33** (and/or an indicator of the portable device **21**) upon detecting a charging error. The controller **27** may also take corrective action responsive to the error condition, such as limiting the charging voltage or current, or terminating charging, as illustratively shown at Block **52**. If no such error is detected, then charging continues until a predetermined event occurs, such as a maximum charging time or charge level being reached, at Block **53**.

In accordance with another advantageous aspect of the invention, the charger connector **24** may also carry communications signals between the controller **27** and the host device. For example, the controller **27** may communicate with the host device over the same differential signal lines D+, D− connected to the charger connector **24**. In particular, the communications signals may relate to one or more charging parameters. That is, the controller **27** may download charging parameters for unknown device/battery types from the host device instead of, or in addition to, downloading charging parameters from portable devices themselves.

Of course, this configuration also allows the charger connector **24** to carry communications signals between the portable device **21** and the host device. In other words, the battery charger **23** may thus be used as a docking station for allowing the portable device **21** to communicate with the host device while it is being charged. This arrangement may be particularly advantageous for portable devices such as PDAs. This is because PDAs not only have portable batteries which typically require regular re-charging, but they also typically need to synchronize calendar, contact, email, and other data with a computer, as will be appreciated by those of skill in the art.

A battery charging method aspect of the invention for a rechargeable battery **22** carried by a portable device **21** includes coupling a device connector **25** of the portable device to a corresponding charger connector **24**, and connecting a charging circuit **26** to the charger connector. The method may further include causing the portable device **21** to identify its corresponding portable device type and its corresponding rechargeable battery type from among a plurality of different portable device types and different battery types, and causing the charging circuit **26** to charge the rechargeable battery **22** based thereon, as previously described above. Additional method aspects will be readily apparent to those skilled in the art based upon the foregoing description and will therefore not be discussed further herein.

EXAMPLE

Turning now to FIG. **5**, an exemplary portable or mobile device **1000** illustratively includes a housing **1200**, a keyboard **1400** and an output device **1600**. The output device shown is a display **1600**, which is preferably a full graphic LCD. Other types of output devices may alternatively be utilized. A processing device **1800** is contained within the housing **1200** and is coupled between the keyboard **1400** and the display **1600**. The processing device **1800** controls the operation of the display **1600**, as well as the overall operation of the mobile device **1000**, in response to actuation of keys on the keyboard **1400** by the user.

The housing **1200** may be elongated vertically, or may take on other sizes and shapes (including clamshell housing structures). The keyboard may include a mode selection key, or other hardware or software for switching between text entry and telephony entry.

In addition to the processing device **1800**, other parts of the mobile device **1000** are shown schematically in FIG. **5**. These include a communications subsystem **1001**; a short-range communications subsystem **1020**; the keyboard **1400** and the display **1600**, along with other input/output devices **1060**, **1080**, **1100** and **1120**; as well as memory devices **1160**, **1180** and various other device subsystems **1201**. The mobile device **1000** is preferably a two-way RF communications device having voice and data communications capabilities. In addition, the mobile device **1000** preferably has the capability to communicate with other computer systems via the Internet.

Operating system software executed by the processing device **1800** is preferably stored in a persistent store, such as the flash memory **1160**, but may be stored in other types of memory devices, such as a read only memory (ROM) or similar storage element. In addition, system software, specific device applications, or parts thereof, may be temporarily loaded into a volatile store, such as the random access memory (RAM) **1180**. Communications signals received by the mobile device may also be stored in the RAM **1180**.

The processing device **1800**, in addition to its operating system functions, enables execution of software applications **1300**A-**1300**N on the device **1000**. A predetermined set of applications that control basic device operations, such as data and voice communications **1300**A and **1300**B, may be installed on the device **1000** during manufacture. In addition, a personal information manager (PIM) application may be installed during manufacture. The PIM is preferably capable of organizing and managing data items, such as e-mail, calendar events, voice mails, appointments, and task items. The PIM application is also preferably capable of sending and receiving data items via a wireless network **1401**. Preferably,

the PIM data items are seamlessly integrated, synchronized and updated via the wireless network **1401** with the device user's corresponding data items stored or associated with a host computer system.

Communication functions, including data and voice communications, are performed through the communications subsystem **1001**, and possibly through the short-range communications subsystem. The communications subsystem **1001** includes a receiver **1500**, a transmitter **1520**, and one or more antennas **1540** and **1560**. In addition, the communications subsystem **1001** also includes a processing module, such as a digital signal processor (DSP) **1580**, and local oscillators (LOs) **1601**. The specific design and implementation of the communications subsystem **1001** is dependent upon the communications network in which the mobile device **1000** is intended to operate. For example, a mobile device **1000** may include a communications subsystem **1001** designed to operate with the Mobitex™, Data TAC™ or General Packet Radio Service (GPRS) mobile data communications networks, and also designed to operate with any of a variety of voice communications networks, such as AMPS, TDMA, CDMA, PCS, GSM, etc. Other types of data and voice networks, both separate and integrated, may also be utilized with the mobile device **1000**.

Network access requirements vary depending upon the type of communication system. For example, in the Mobitex and DataTAC networks, mobile devices are registered on the network using a unique personal identification number or PIN associated with each device. In GPRS networks, however, network access is associated with a subscriber or user of a device. A GPRS device therefore requires a subscriber identity module, commonly referred to as a SIM card, in order to operate on a GPRS network.

When required network registration or activation procedures have been completed, the mobile device **1000** may send and receive communications signals over the communication network **1401**. Signals received from the communications network **1401** by the antenna **1540** are routed to the receiver **1500**, which provides for signal amplification, frequency down conversion, filtering, channel selection, etc., and may also provide analog to digital conversion. Analog-to-digital conversion of the received signal allows the DSP **1580** to perform more complex communications functions, such as demodulation and decoding. In a similar manner, signals to be transmitted to the network **1401** are processed (e.g. modulated and encoded) by the DSP **1580** and are then provided to the transmitter **1520** for digital to analog conversion, frequency up conversion, filtering, amplification and transmission to the communication network **1401** (or networks) via the antenna **1560**.

In addition to processing communications signals, the DSP **1580** provides for control of the receiver **1500** and the transmitter **1520**. For example, gains applied to communications signals in the receiver **1500** and transmitter **1520** may be adaptively controlled through automatic gain control algorithms implemented in the DSP **1580**.

In a data communications mode, a received signal, such as a text message or web page download, is processed by the communications subsystem **1001** and is input to the processing device **1800**. The received signal is then further processed by the processing device **1800** for an output to the display **1600**, or alternatively to some other auxiliary I/O device **1060**. A device user may also compose data items, such as e-mail messages, using the keyboard **1400** and/or some other auxiliary I/O device **1060**, such as a touchpad, a rocker switch, a thumb-wheel, or some other type of input device. The composed data items may then be transmitted over the communications network **1401** via the communications subsystem **1001**.

In a voice communications mode, overall operation of the device is substantially similar to the data communications mode, except that received signals are output to a speaker **1100**, and signals for transmission are generated by a microphone **1120**. Alternative voice or audio I/O subsystems, such as a voice message recording subsystem, may also be implemented on the device **1000**. In addition, the display **1600** may also be utilized in voice communications mode, for example to display the identity of a calling party, the duration of a voice call, or other voice call related information.

The short-range communications subsystem enables communication between the mobile device **1000** and other proximate systems or devices, which need not necessarily be similar devices. For example, the short-range communications subsystem may include an infrared device and associated circuits and components, or a Bluetooth communications module to provide for communication with similarly-enabled systems and devices.

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

That which is claimed is:

1. A battery charger for a portable wireless communications device, the portable wireless communications device including a rechargeable battery and a wireless communications transceiver coupled thereto, the portable wireless communications device and rechargeable battery each respectively having a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different rechargeable battery types having respective charging rates, the battery charger comprising:

a charging circuit; and

a controller coupled to said charging circuit and configured to cause the portable wireless communications device to identify its corresponding portable device type and its corresponding rechargeable battery type, and to cause said charging circuit to charge the rechargeable battery based on the respective charging rate thereof.

2. The battery charger of claim **1** wherein different portable device types have at least one different portable device charging parameter; wherein different battery types have at least one different battery charging parameter; and wherein said controller is configured to select at least one actual charging parameter to charge the rechargeable battery based upon a comparison of the at least one different portable device charging parameter and at least one different battery charging parameter.

3. The battery charger of claim **2** wherein said controller is configured to select the at least one actual charging parameter based upon a limiting one of the at least one different portable device charging parameter and the at least one different battery charging parameter.

4. The battery charger of claim **2** wherein said controller is configured to further cause the portable wireless communications device to identify a battery charge level; and wherein said controller is configured to further select the at least one actual charging parameter based upon the battery charge level.

5. The battery charger of claim 2 wherein said controller is configured to enter a learning mode for learning the at least one different portable device or battery charging parameter upon receiving a learning mode signal therefrom.

6. The battery charger of claim 2 further comprising at least one memory coupled to said controller and configured to store the at least one different portable device charging parameter and the at least one different battery charging parameter.

7. The battery charger of claim 2 wherein the at least one actual charging parameter comprises at least one of a voltage parameter, and a charging time.

8. The battery charger of claim 1 wherein said controller is configured to further provide an error signal to the portable wireless communications device based upon an unknown portable device type or rechargeable battery type.

9. The battery charger of claim 1 wherein said controller is configured to monitor said charging circuit to detect a charging error during charging of the rechargeable battery.

10. The battery charger of claim 9 further comprising an indicator connected to said controller and configured to provide an error indication upon detecting the at least one charging error.

11. A battery charging system comprising:

a portable wireless communications device including a rechargeable battery and a wireless communications transceiver coupled thereto, said portable wireless communications device and rechargeable battery each respectively having a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different rechargeable battery types having respective charging rates; and

a battery charger comprising

a charging circuit, and

a controller coupled to said charging circuit and configured to cause said portable wireless communications device to identify its corresponding portable device type and its corresponding rechargeable battery type, and to cause said charging circuit to charge the rechargeable battery based on the respective charging rate thereof.

12. The battery charging system of claim 11 wherein different portable device types have at least one different portable device charging parameter; wherein different battery types have at least one different battery charging parameter; and wherein said controller is configured to select at least one actual charging parameter to charge the rechargeable battery based upon a comparison of the at least one different portable device charging parameter and at least one different battery charging parameter.

13. The battery charging system of claim 12 wherein said controller is configured to select the at least one actual charging parameter based upon a limiting one of the at least one different portable device charging parameter and the at least one different battery charging parameter.

14. The battery charging system of claim 12 wherein said controller is configured to further cause the portable wireless communications device to identify a battery charge level; and wherein said controller is configured to further select the at least one actual charging parameter based upon the battery charge level.

15. The battery charging system of claim 12 wherein said controller is configured to enter a learning mode for learning the at least one different portable device or battery charging parameter upon receiving a learning mode signal therefrom.

16. The battery charging system of claim 12 further comprising at least one memory coupled to said controller and configured to store the at least one different portable device charging parameter and the at least one different battery charging parameter.

17. The battery charging system of claim 12 wherein the at least one actual charging parameter comprises at least one of a voltage parameter, and a charging time.

18. A battery charging method for a rechargeable battery carried by a portable wireless communications device, the portable wireless communications device and rechargeable battery each respectively having a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different battery types having respective charging rates, the method comprising:

coupling a charging circuit to the portable wireless communications device to cause the portable wireless communications device to identify its corresponding portable device type and its corresponding rechargeable battery type, and causing the charging circuit to charge the rechargeable battery based on the respective charging rate thereof.

19. The method of claim 18 wherein different portable device types have at least one different portable device charging parameter; wherein different battery types have at least one different battery charging parameter; and further comprising selecting at least one actual charging parameter to charge the rechargeable battery based upon a comparison of the at least one different portable device charging parameter and at least one different battery charging parameter.

20. The method of claim 19 wherein selecting comprises selecting the at least one actual charging parameter based upon a limiting one of the at least one different portable device charging parameter and the at least one different battery charging parameter.

21. The method of claim 19 further comprising causing the portable wireless communications device to identify a battery charge level of the rechargeable battery; and wherein selecting comprises selecting the at least one actual charging parameter further based upon the battery charge level.

22. The method of claim 19 wherein the at least one actual charging parameter comprises at least one of a voltage parameter and a charging time.

* * * * *

EXHIBIT D

US008545247B2

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

(10) **Patent No.: US 8,545,247 B2**
(45) **Date of Patent: Oct. 1, 2013**

(54) **DOCK FOR A PORTABLE ELECTRONIC DEVICE**

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(73) Assignee: **BlackBerry Limited**, Waterloo (CA)

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

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(22) Filed: **Feb. 15, 2012**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
H01R 13/64 (2006.01)

(52) **U.S. Cl.**
USPC **439/248**; 439/929

(58) **Field of Classification Search**
USPC 439/246–248, 929
See application file for complete search history.

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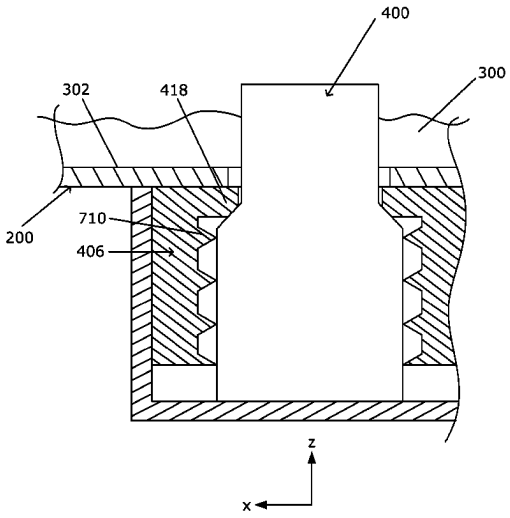
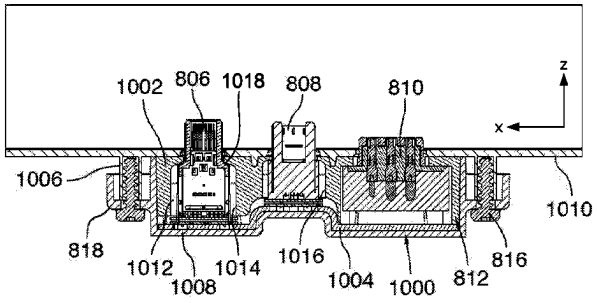
Primary Examiner — Ross Gushi
(74) *Attorney, Agent, or Firm* — Lesley M. Morrison; Borden Ladner Gervais LLP

(57) **ABSTRACT**

A dock for receiving a portable electronic device, including a housing comprising an aperture; a support coupled to an inner wall of the housing, a portion of the support being elastically deformable; and a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data to an electronic device; wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.

19 Claims, 16 Drawing Sheets





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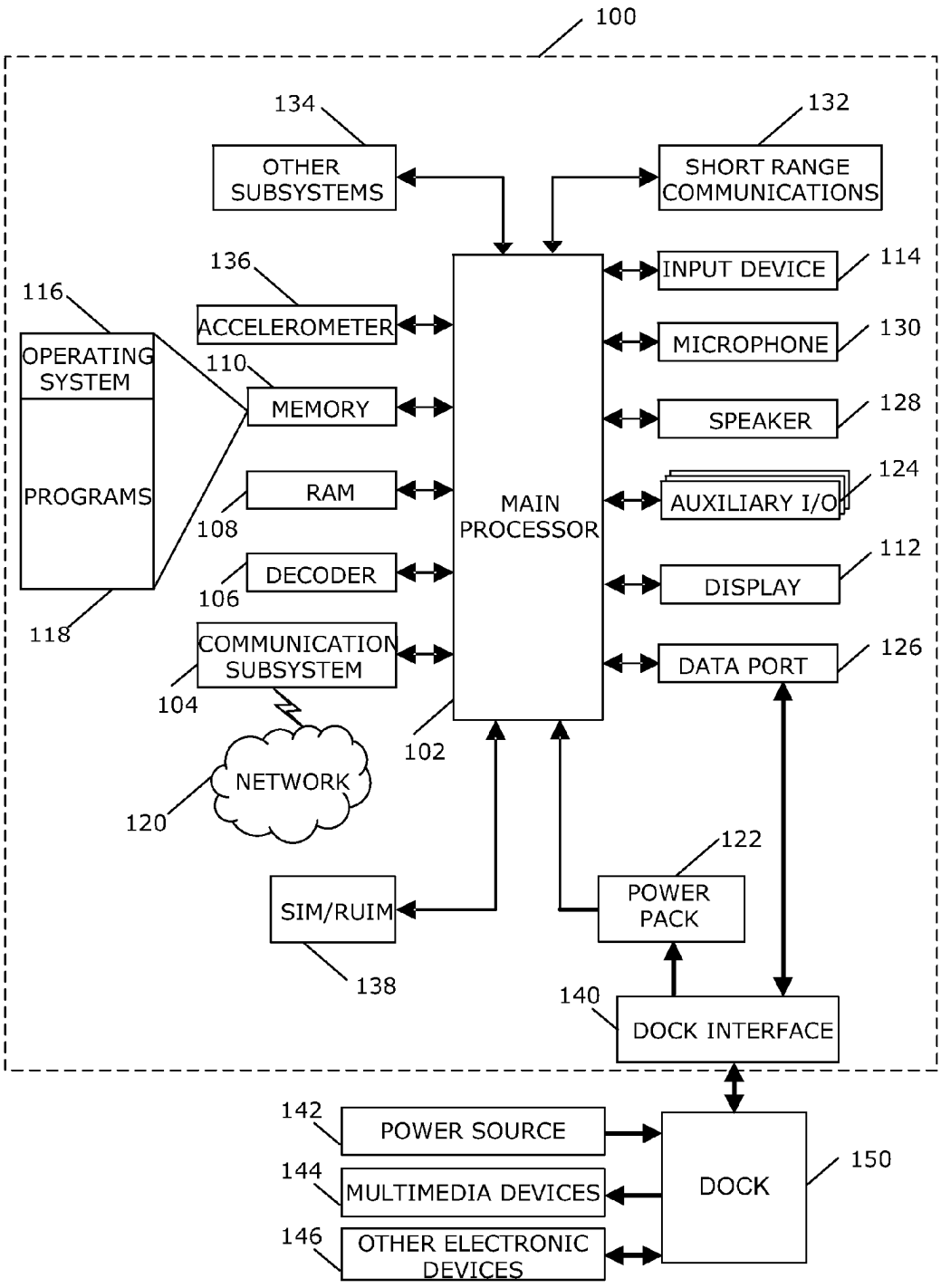
100
134
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SHORT RANGE COMMUNICATIONS
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ACCELEROMETER
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OPERATING SYSTEM
PROGRAMS
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DECODER
106
118
COMMUNICATION SUBSYSTEM
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NETWORK
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MAIN PROCESSOR
102
INPUT DEVICE
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MICROPHONE
130
SPEAKER
128
AUXILIARY I/O
124
DISPLAY
112
DATA PORT
126
SIM/RUIM
138
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OTHER ELECTRONIC DEVICES
DOCK
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FIG. 1

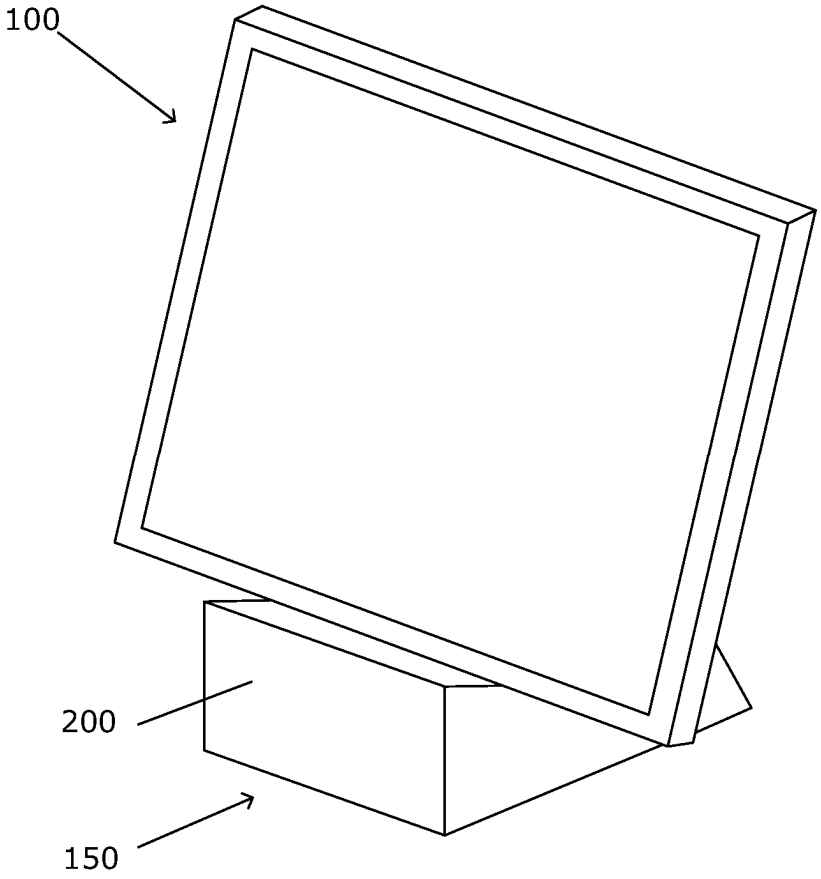

FIG. 2

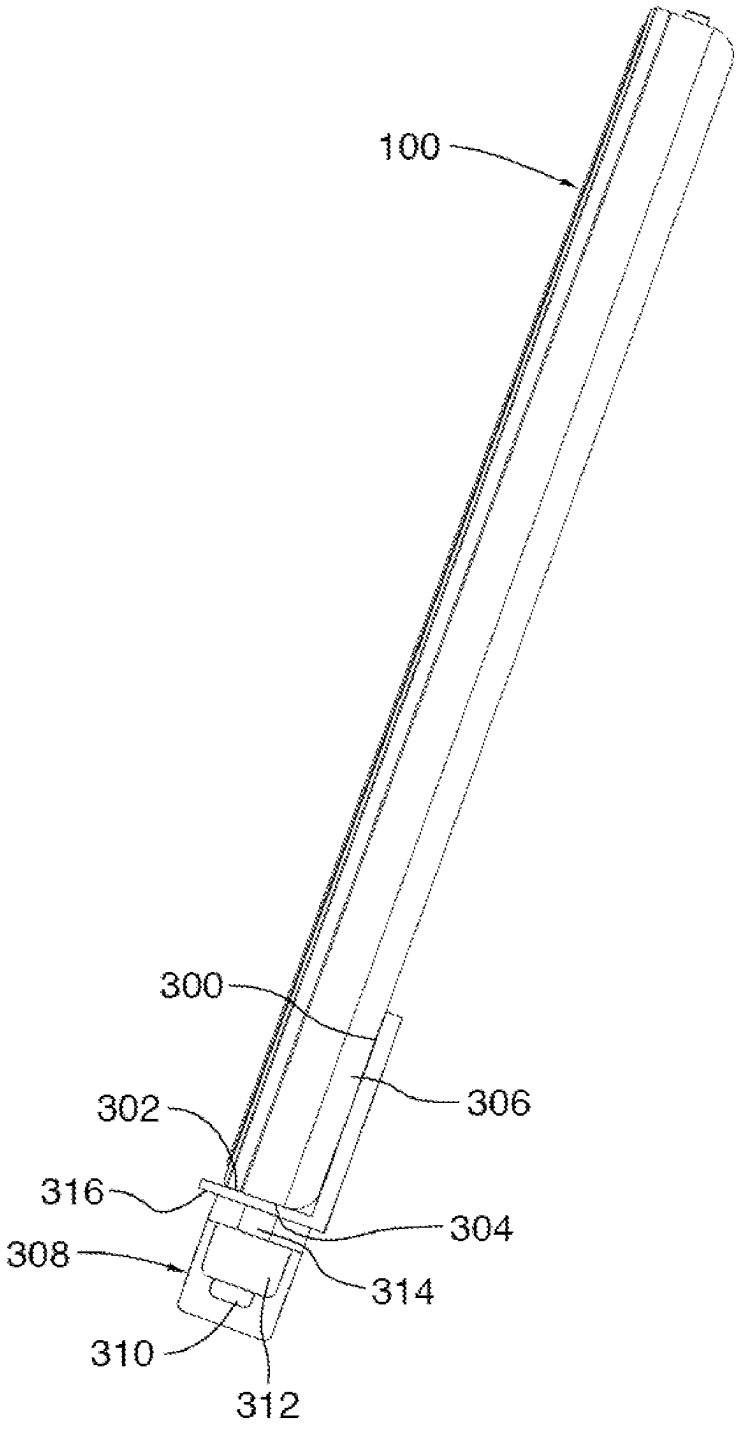

FIG. 3

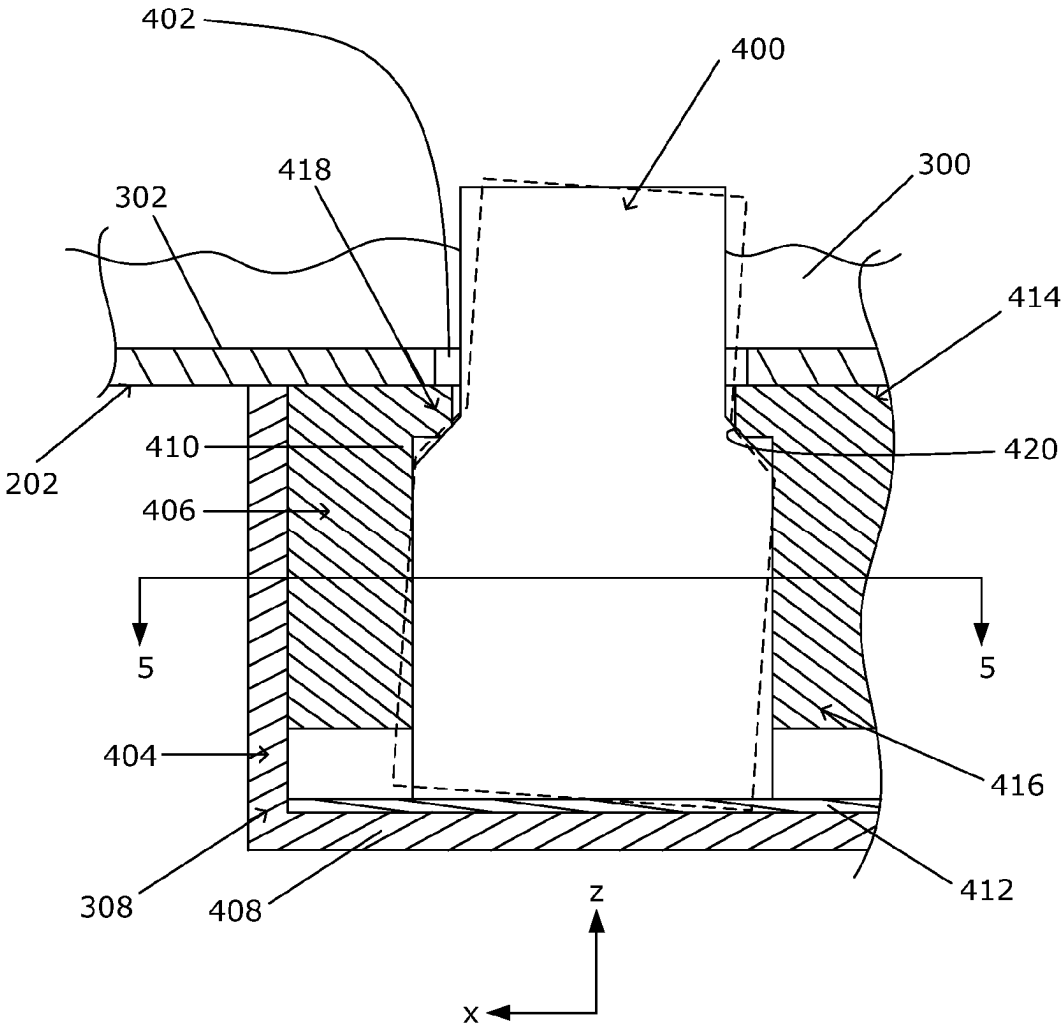

FIG. 4

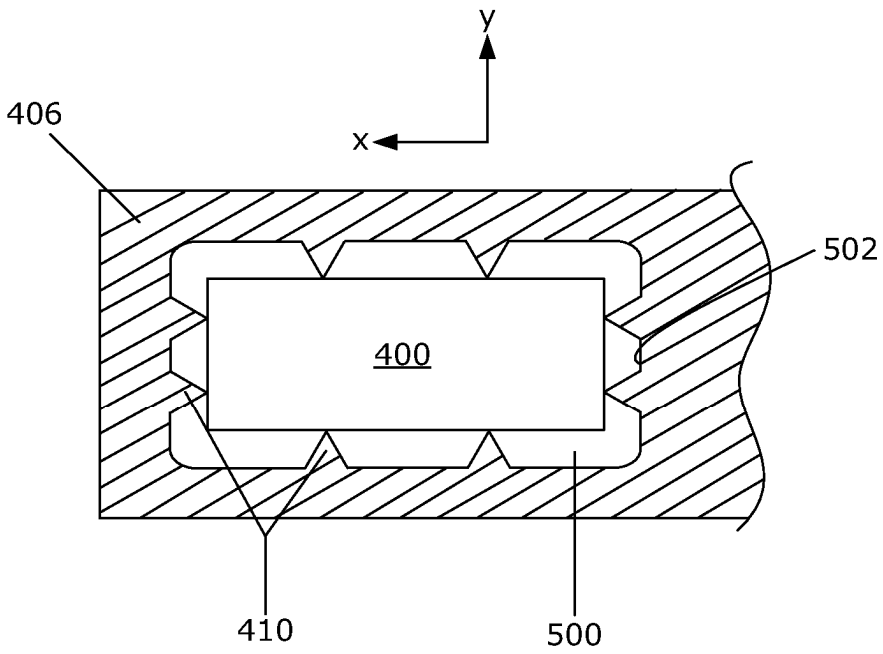

FIG. 5

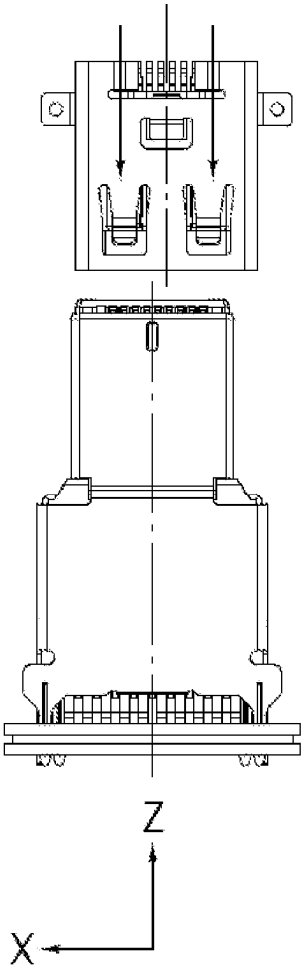

FIG. 6A

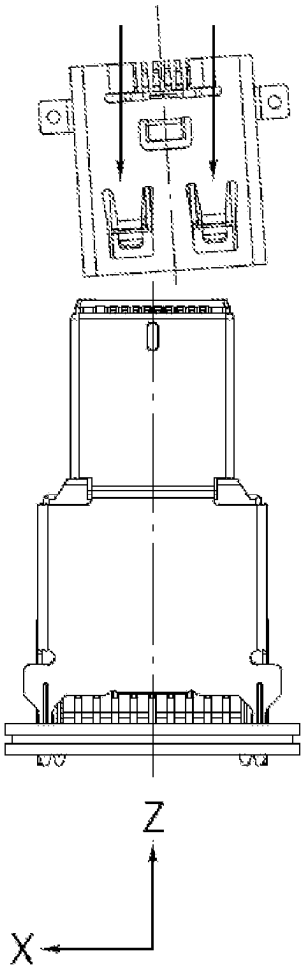

FIG. 6B

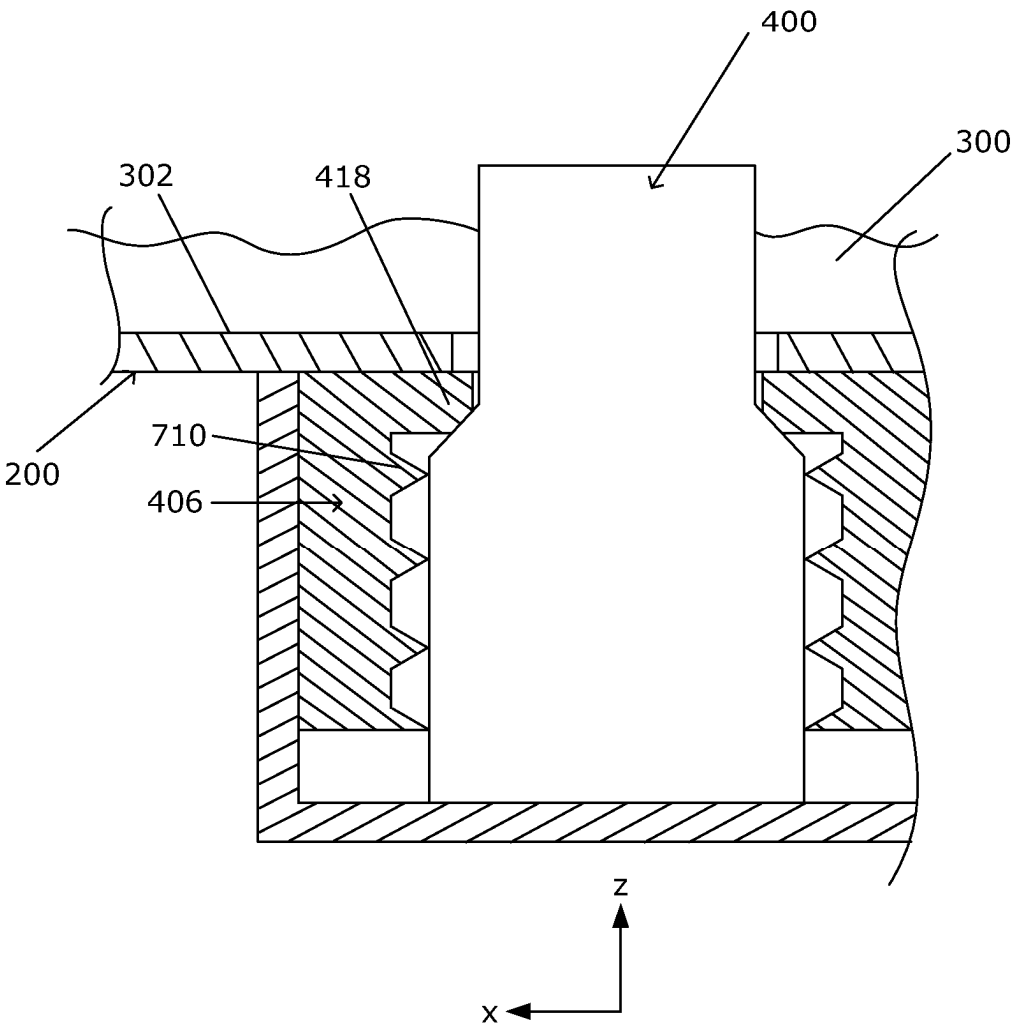

FIG. 7

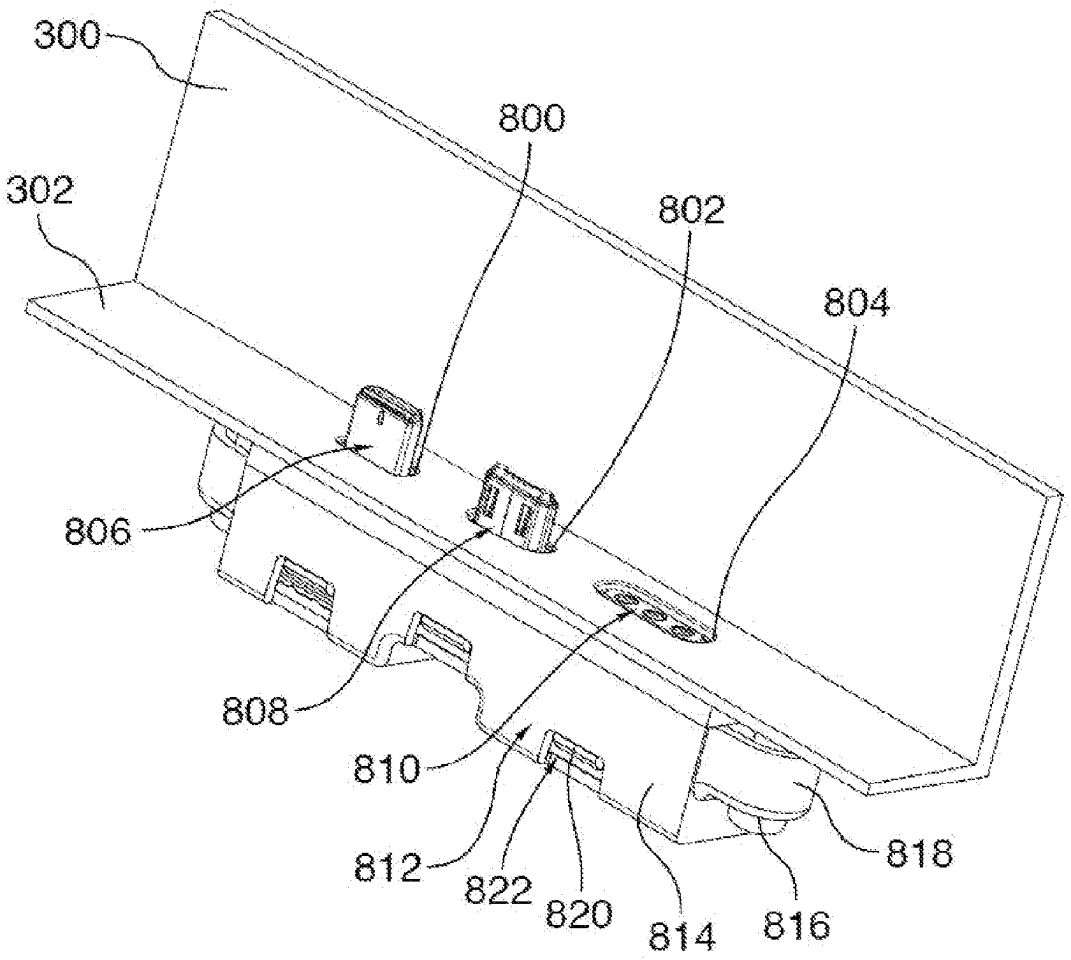

FIG. 8

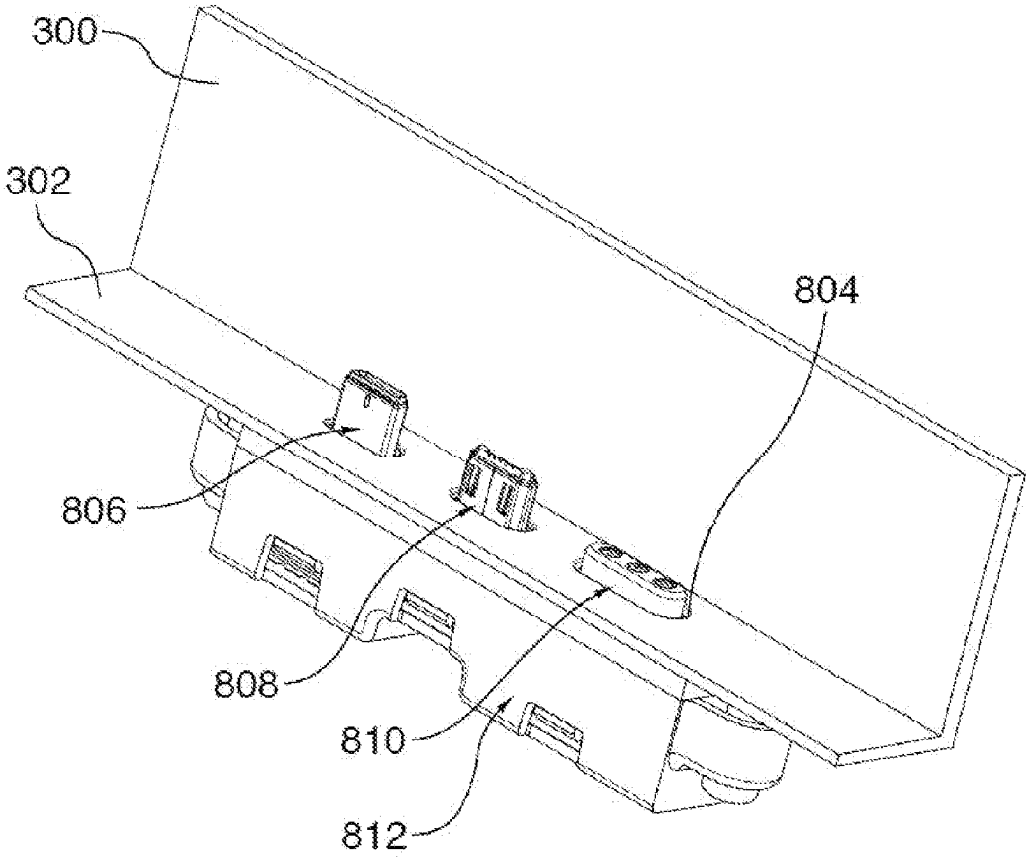

FIG. 9

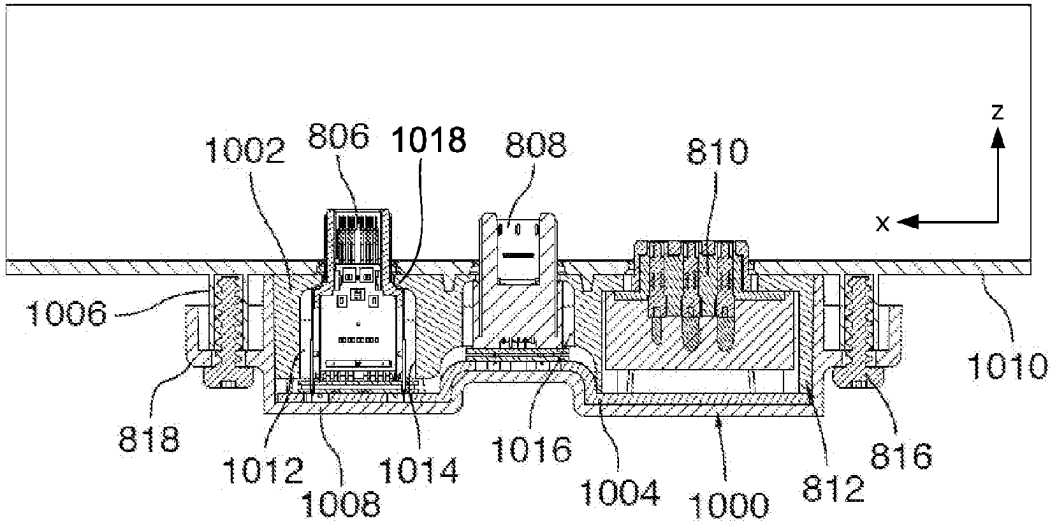
1002
806
1018
808
810
z
x
1006
1010
818
1012
1008
1014
1016
1004
1000
812
816

FIG. 10

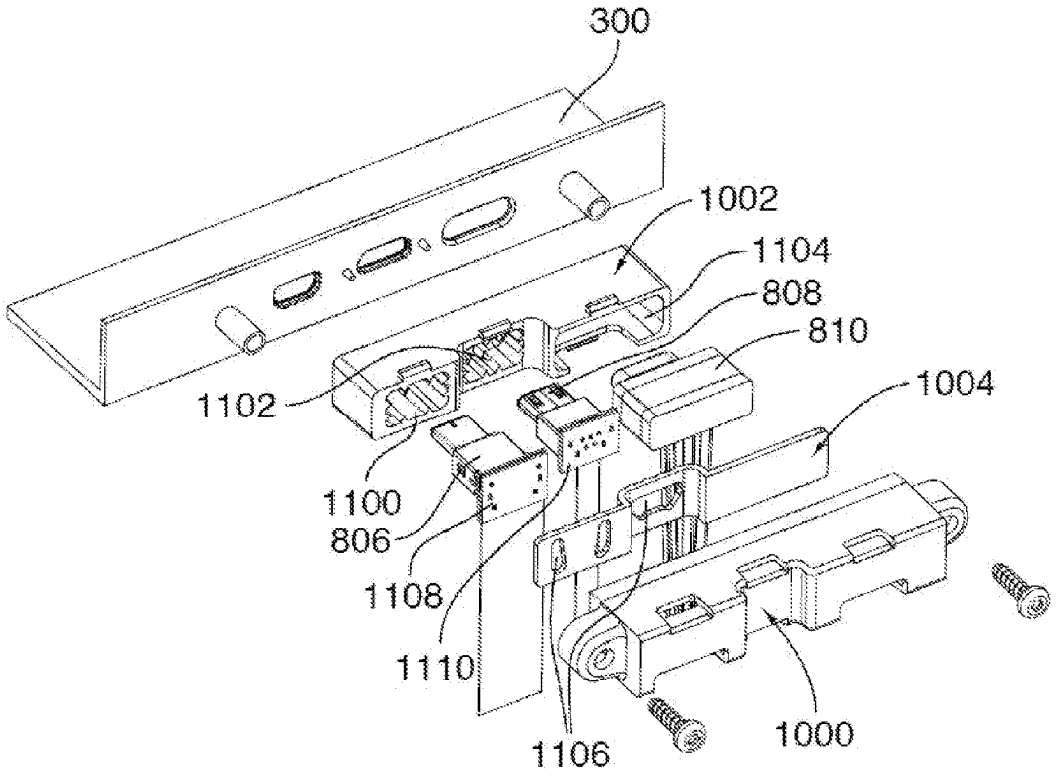

FIG. 11

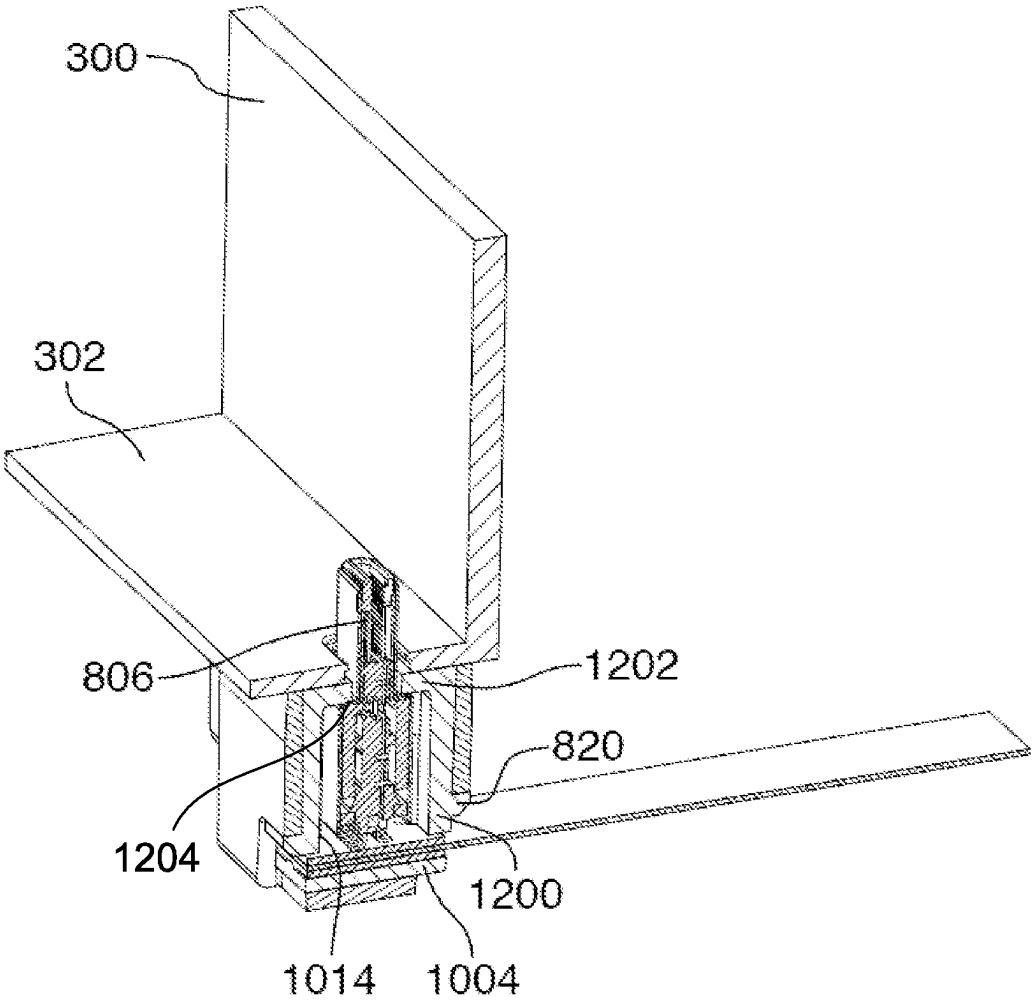

FIG. 12

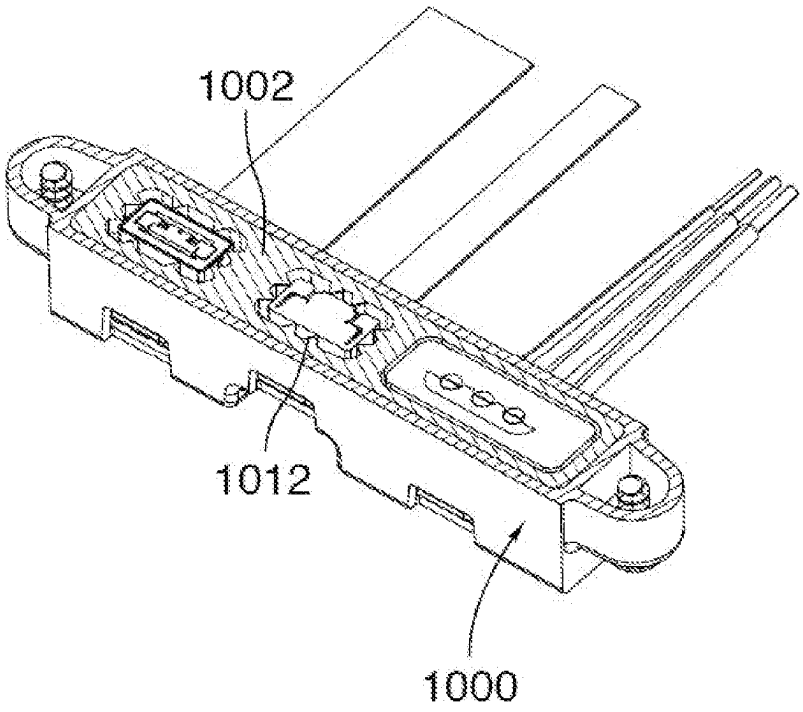

FIG. 13

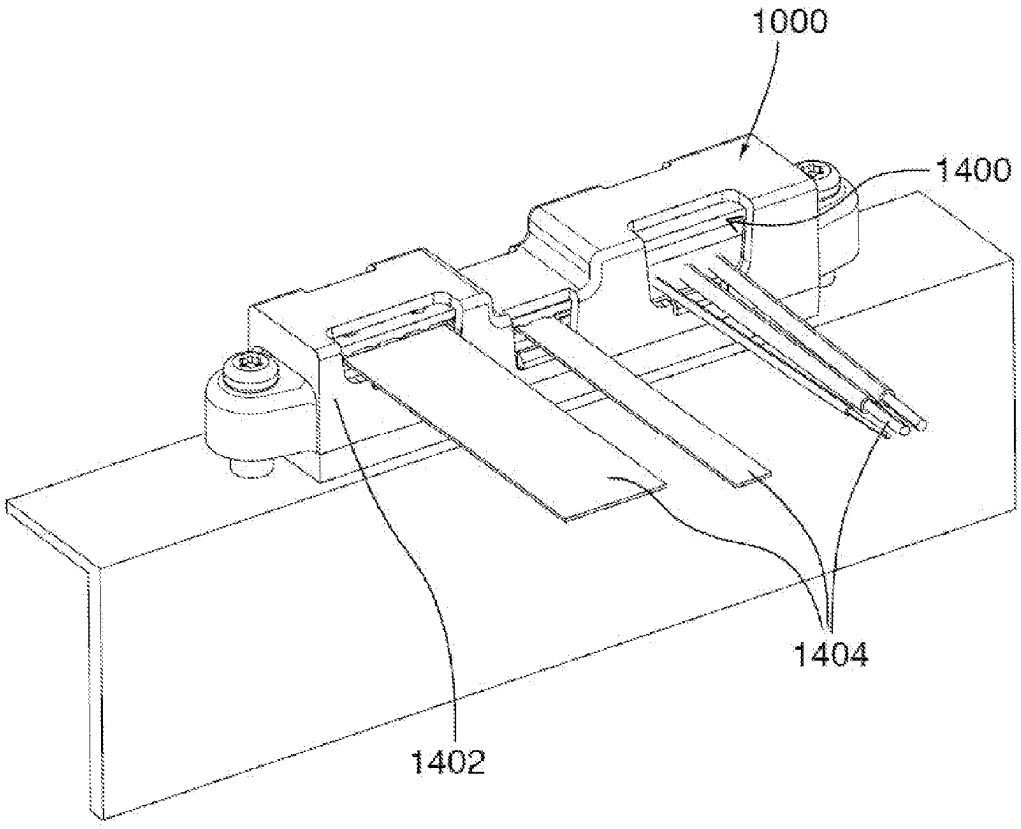

FIG. 14

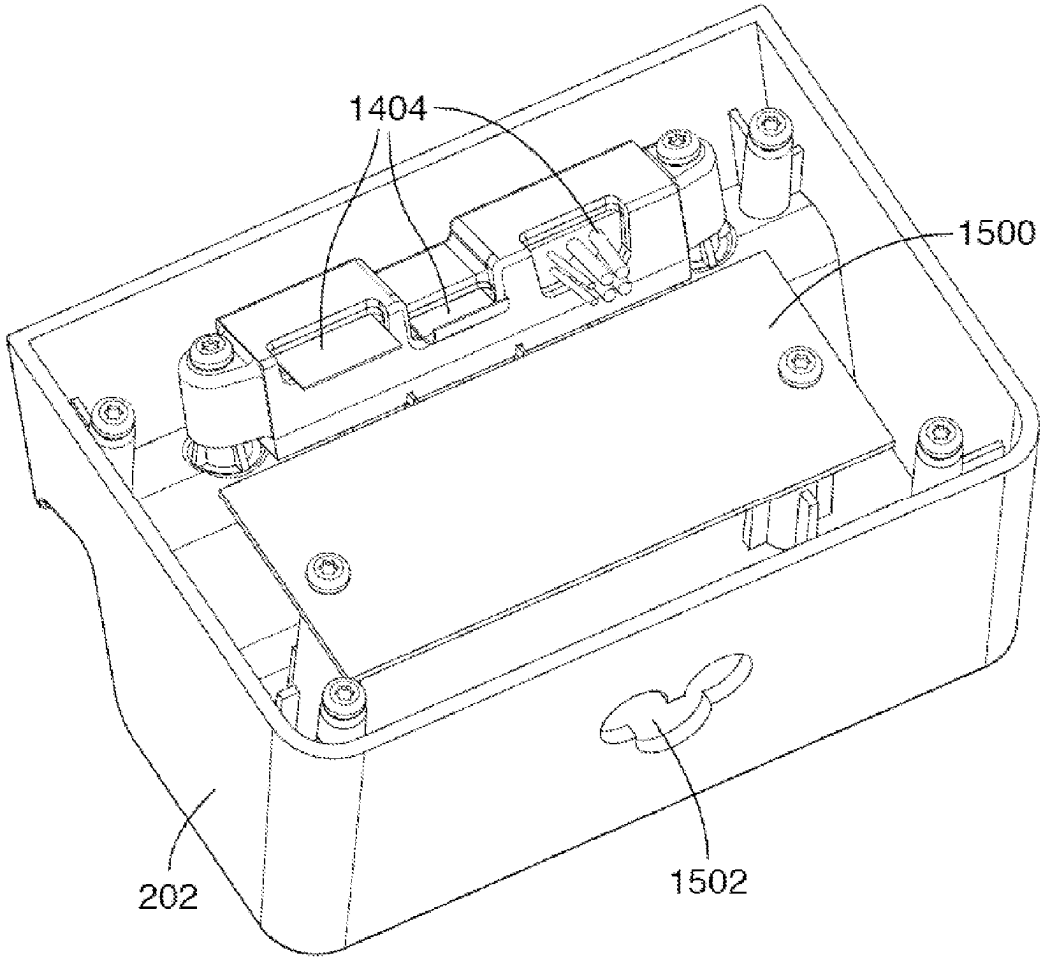

FIG. 15

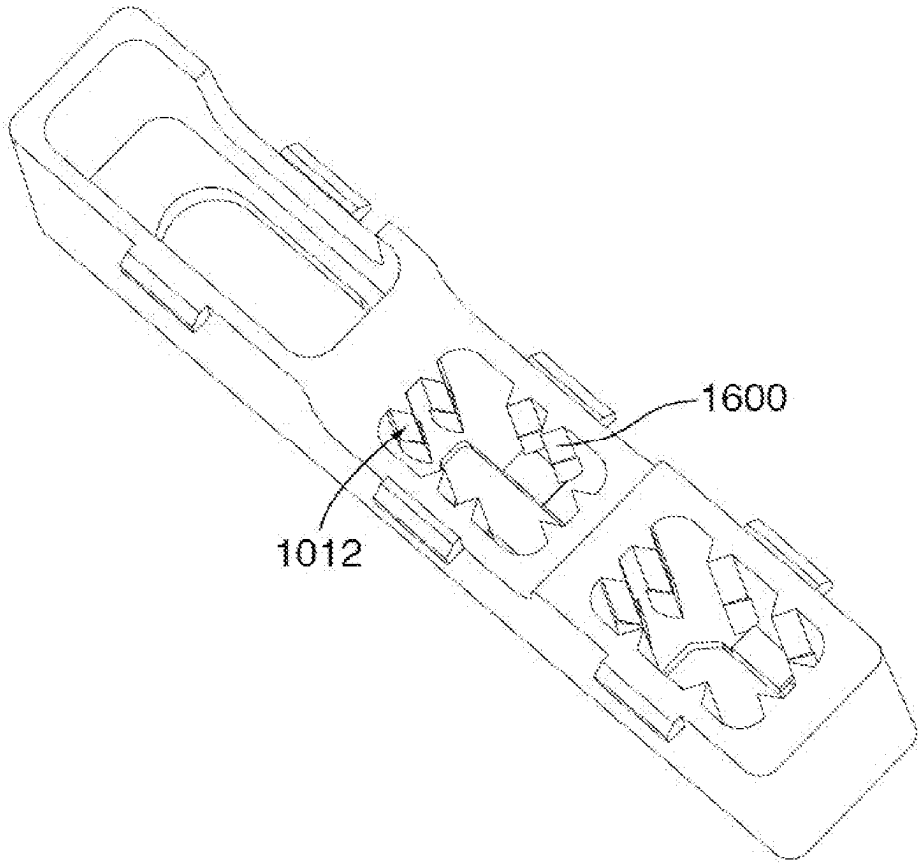

FIG. 16

DOCK FOR A PORTABLE ELECTRONIC DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of priority of U.S. Provisional Patent Application No. 61/503,451, filed on Jun. 30, 2011, which incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present application relates to charging and/or data transfer docks for portable electronic devices.

BACKGROUND DISCUSSION

Electronic devices, including portable electronic devices, have gained widespread use and may provide a variety of functions including, for example, telephonic, electronic messaging and other personal information manager (PIM) application functions. Portable electronic devices include, for example, several types of mobile stations such as simple cellular telephones, smart telephones, wireless personal digital assistants (PDAs), tablets and laptop computers with wireless 802.11 or Bluetooth capabilities.

Portable electronic devices such as PDAs or smart telephones are generally intended for handheld use (that is, the devices are sized and shaped to be held or carried in a human hand) and ease of portability. Portable electronic devices are often placed in docks for charging or data transfer including transfer of information in any form optically or electrically from dock to portable electronic device and vice versa. Some docks are capable of both charging and data transfer. Docks and portable electronic devices are susceptible to damage due to connection attempts when the portable electronic device and the dock are not properly aligned.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present application will now be described, by way of example only, with reference to the attached Figures, wherein:

FIG. **1** is a simplified block diagram of components including internal components of a portable electronic device;

FIG. **2** is an isometric view of a portable electronic device received in a dock according to an example;

FIG. **3** is a side view of a portable electronic device received in the dock of FIG. **2** with a portion of a housing of the dock removed;

FIG. **4** is a front sectional view of portions of the dock of FIG. **2**;

FIG. **5** is a top sectional view on **5-5** of FIG. **4** of portions of the dock of FIG. **2**;

FIGS. **6**A and **6**B are schematic front views of a mating connector of a portable electronic device misaligned with a connector of a dock;

FIG. **7** is a front sectional view of portions of a dock according to another example;

FIG. **8** is an isometric view of a dock according to another example with a charging connector in a stowed position;

FIG. **9** is an isometric view of the dock of FIG. **8** with a charging connector in an extended position;

FIG. **10** is a front sectional view of the dock of FIG. **8**;

FIG. **11** is an exploded view of the dock of FIG. **8**;

FIG. **12** is an isometric side sectional view of the dock of FIG. **8**;

FIG. **13** is an isometric top sectional view of the dock of FIG. **8**;

FIG. **14** is an isometric rear bottom view of the dock of FIG. **8**;

FIG. **15** is an isometric view similar to FIG. **14** including additional components of the dock; and

FIG. **16** is an isometric bottom sectional view of a spring component of a dock according to another example.

DETAILED DESCRIPTION

The following describes a dock for receiving a portable electronic device. The dock includes a support for a connector including an elastically deformable portion for allowing movement of the connector relative to the dock when a force is applied.

In an aspect of the present disclosure, there is provided a dock for receiving a portable electronic device, including: a housing comprising an aperture; a support coupled to an inner wall of the housing, a portion of the support being elastically deformable; and a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device; wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.

In another aspect of the present disclosure, there is provided a connector assembly for a dock, the connector assembly including: a support for coupling to an inner wall the dock, a portion of the support being elastically deformable; and a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device; wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.

For simplicity and clarity of illustration, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. Numerous details are set forth to provide an understanding of the embodiments described herein. The embodiments may be practiced without these details. In other instances, well-known methods, procedures, and components have not been described in detail to avoid obscuring the embodiments described. The description is not to be considered as limited to the scope of the embodiments described herein.

The disclosure generally relates to a dock for a portable electronic device in the embodiments described herein. The dock may receive portable electronic devices including: mobile, or handheld, wireless communication devices such as pagers, cellular phones, cellular smart-phones, wireless organizers, tablets, global positioning system devices and personal digital assistants, for example. The portable electronic device may also be a portable electronic device without wireless communication capabilities, such as a handheld electronic game device, digital photograph album, digital camera, or other device. The portable electronic device may be, but need not be, a handheld device.

A block diagram of an example of a portable electronic device **100** is shown in FIG. **1**. The portable electronic device **100** includes multiple components, such as a processor **102** that controls the overall operation of the portable electronic device **100**. Communication functions, including data and voice communications, are performed through a communica-

tion subsystem **104**. Data received by the portable electronic device **100** is decompressed and decrypted by a decoder **106**. The communication subsystem **104** receives messages from and sends messages to a wireless network **120**. The wireless network **120** may be any type of wireless network, including, but not limited to, data wireless networks, voice wireless networks, and networks that support both voice and data communications.

A power pack **122**, such as one or more rechargeable batteries or a port to an external power supply, powers the portable electronic device **100**. A dock interface **140** may electrically communicate with a dock **150** to charge the power pack **122** and/or provide a data connection to a data port **126** of the portable electronic device **100**. In general, components electrically communicate with one another when the electrical activity in one component affects an electrical activity in another. Electrical communication includes direct electrical contact that enables current flow. The dock interface **140** may include one or more mating connectors for electrically communicating with connectors of the dock **150**. The dock **150** may electrically communicate with one or more of a power source **142**, multimedia devices **144** such as televisions, monitors, projectors or other output devices, for example, and other electronic devices **146**. In some situations, communication may be electrical or optical or a combination of electrical and optical.

The processor **102** interacts with other components, such as Random Access Memory (RAM) **108**, memory **110**, a display **112**, an input device **114**, an auxiliary input/output (I/O) subsystem **124**, a data port **126**, a speaker **128**, a microphone **130**, short-range communications **132**, and other device subsystems **134**. The processor **102** may interact with an orientation sensor such as an accelerometer **136** that may be utilized to detect direction of gravitational forces or gravity-induced reaction forces.

To identify a subscriber for network access, the portable electronic device **100** uses a Subscriber Identity Module or a Removable User Identity Module (SIM/RUIM) card **138** for communication with a network, such as the wireless network **120**. Alternatively, user identification information may be programmed into memory **110**.

The portable electronic device **100** includes an operating system **116** and software programs or components **118** that are executed by the processor **102** and are typically stored in a persistent, updatable store such as the memory **110**. Additional applications or programs may be loaded onto the portable electronic device **100** through the wireless network **120**, the auxiliary I/O subsystem **124**, the data port **126**, the short-range communications subsystem **132**, or any other suitable subsystem **134**.

A received signal such as a text message, an e-mail message, or web page download is processed by the communication subsystem **104** and input to the processor **102**. The processor **102** processes the received signal for output to the display **112** and/or to the auxiliary I/O subsystem **124**. A subscriber may generate data items, for example e-mail messages, which may be transmitted over the wireless network **120** through the communication subsystem **104**. For voice communications, the overall operation of the portable electronic device **100** is similar. The speaker **128** outputs audible information converted from electrical signals, and the microphone **130** converts audible information into electrical signals for processing.

An example dock **150** for receiving a portable electronic device **100** is shown in FIGS. **2** and **3**. The dock **150** includes a housing **200** that is shaped to receive the portable electronic device **100**. In one example, the housing **200** includes a seat **302** and a support wall **300** for receiving the portable electronic device **100**. In general, the support wall **300** and the seat **302** support the weight of a received portable electronic device **100**, although in some of the embodiments depicted herein, the seat **302** may support more weight than the support wall **300**. As shown in FIG. **3**, an edge surface **304** of the portable electronic device **100** contacts the seat **302** of the housing **200** and a rear surface **306** of the portable electronic device **100** contacts the support wall **300** of the housing **200**. The size and shape of the seat **302** and the support wall **300** and the angle between the seat **302** and the support wall **300** may be selected to accommodate different sizes and types of portable electronic devices **100**.

The housing **200** may be molded plastic, machined metal or wood, for example. The housing may be a single part or may be an assembly of multiple parts.

The dock **150** includes a connector support assembly **308** that is coupled to an inner surface of the housing **200**. In general, components are coupled to one another when movement of one component affects movement in the other component. Coupling may be permanent, such as by welding for example, or may be reversible, such as connection by fasteners, for example. Coupling may include direct contact between the two components or the components may be spaced from one another with additional components being provided to achieve coupling between the two components. In one example, screws **310** couple lugs **312** of the support assembly **308** to screw-receiving components **314**, which extend from an underside surface **316** of the seat **302**, to couple the support assembly **308** to the housing **200**.

Referring also to FIG. **4**, the connector support assembly **308** receives a connector **400**. The connector **400** may be a charging connector, a data connector or a connector capable of both charging and data transfer. The connector **400** may support an electrical connection, an optical connection or a combination thereof. A connecting portion of the connector **400** extends through an aperture **402**, which is located in the seat **302**. When the portable electronic device **100** is received in the dock **150**, the connector **400** electrically or optically communicates with the portable electronic device **100** to charge the portable electronic device **100** and/or provide a data connection thereto. In general, the portable electronic device **100** is received in the dock **150** when the portable electronic device **100** is generally supported thereby. Similarly, a first component may be received in a second component when the first component is supported by the second component. The first component may or may not be coupled to the second component and may move relative to the second component.

The connector support assembly **308** includes a support **404**, a spring component **406**, which is received in the support **404**, and a flexible pad **412**, which is located on a base **408** of the support **404**. The base **408** of the support **404** limits movement of the connector **400** in a z-direction to facilitate coupling with a mating connector of the portable electronic device **100**. An opening (not shown) is provided in the support **404** to allow wiring (such as electrical conductors or optical cables, not shown) of the connector **400** to pass therethrough.

The spring component **406** includes a passage **500**, which is shown in FIG. **5**, for receiving the connector **400**. The passage **500** extends between a top end **414** of the spring component **406** and a bottom end **416** of the spring component **406**. A collar **418** is located at the top end **414** of the spring component **406** and ribs **410** extend from an inner wall **502** of the passage **500**. The collar **418** includes a contact surface **420**, which abuts the connector **400** to limit transla-

tion of the connector **400** in the x and y directions. The collar **418** may fully or partially surround the connector **400**.

The ribs **410** extend vertically relative to the passage **500** and are elastically deformable to accommodate movement of the connector **400**. The ribs **410** contact the connector **400** in order to maintain the connector **400** in a starting position within the passage **500**. The spring component **406** is biased toward the starting position, which is a non-deformed shape shown in FIG. **5**. Any non-axial movement of the connector **400** may cause the ribs **410** of the spring component **406** to elastically deform. An amount of movement of the connector **400** relative to the connector support assembly **308** may be determined by one of both of a rigidity of the ribs **410** and a size of the aperture **402**.

The pad **412** is elastically deformable to accommodate some movement of the connector **400** in the z direction. Movement may occur in response to a force applied in the z-axis or pivoting of the connector **400**. The pad **412** may be interference fit with the connector **400** to bias the connector **400** toward the mating connector of the portable electronic device **100** and absorb tolerances. The pad **412** is biased toward a non-deformed shape, as shown in FIG. **4**.

The spring component **406** is made from a flexible material such as silicone rubber, urethane rubber or cork, for example. A hard plastic having flexible fingers may alternatively be used. The spring component **406** may fully surround the connector **400**, as shown in FIG. **5**, or may partially surround the connector **400**. The spring component **406** may include a different number of ribs than shown in the figures. Further, the spring component may be any spring component that allows movement of the connector **400** relative to the connector support assembly **308** and biases the connector **400** to the starting position within aperture **402**.

In operation, a user visually and/or tactilely aligns a mating connector of the portable electronic device **100** with the connector **400** of the dock **150** and then moves the mating connector into engagement with the connector **400**. When the mating connector is misaligned with the connector **400** in the x and/or y directions, a force is imparted on the connector **400** by the portable electronic device **100**. The ribs **410** of the spring component **406** and the pad **412** elastically deform in order to accommodate pivoting of the connector **400** in response to the force. An example of a pivoted position of the connector **400** is shown in dashed lines in FIG. **4**. Multiple forces may be applied to the connector **400** in various different directions while the user attempts to join the connectors of the portable electronic device **100** and dock **150**. Because the example dock **150** of FIG. **2** includes a single connector **400**, the ribs **410** of the spring component **406** return the connector **400** and the portable electronic device **100** back to the starting position once the connection with the portable electronic device **100** is complete. For heavy portable electronic devices **100**, the ribs **410** may remain in a deformed position until the portable electronic device **100** is removed from the dock **150**.

Two examples of misalignment between mating connector of the portable electronic device **100** and the connector **400** are shown in FIGS. **6**A and **6**B. The dock **150** described herein generally avoids damage to the connector **400** because the force imparted by the mating connector of the portable electronic device **100** is absorbed by the spring component **406** rather than the connector **400**.

The connector support assembly **308** may be any support that is coupled to the housing **200** and includes a portion that elastically deforms in response to movement of the connector **400**. In addition, an alignment component may be provided to facilitate location of the mating connector of the portable electronic device **100** relative to the connector **400**. The alignment component may be a rail, pin or slot, for example, for guiding the portable electronic device **100** into position.

In another example, ribs **710**, which are shown in FIG. **7**, extend generally horizontally in the spring component **406**. The orientation of the ribs may alternatively be disposed at an angle that is between vertical and horizontal.

In another example, the connector extends through an aperture in the support wall or other location in order to accommodate different locations of portable electronic device mating connectors.

Although the collar **418** is shown as part of the spring component **406**, the collar **418** may alternatively form part of the seat **302**. In another example, the spring component **406** does not include a collar **418**. In this embodiment, both translation in the x and y directions and pivoting of the connector **400** relative to the housing **200** are possible.

Referring now to FIGS. **8** and **9**, another example of a dock **150** for a portable electronic device **100** is generally shown. In this example, the dock **150** includes apertures **800**, **802**, **804**, which extend through the seat **302** of the housing **200**. First and second data connectors **806** and **808** extend through apertures **800** and **802**, respectively. A charging connector **810** extends through the aperture **804**. When the portable electronic device **100** is received in the dock **150**, the connectors **806**, **808**, **810** electrically communicate with the portable electronic device **100** to provide data connections and charge the portable electronic device **100**. In one example, the first data connector **806** is a micro HDMI connector for transferring data to multimedia devices and the second data connector **808** is a micro USB connector for exchanging data with other electronic devices. Other types of data connectors are also possible. In addition, the charging connector **810** may also transfer data.

The connectors **806**, **808**, **810** are mounted in a connector support assembly **812**, which is coupled to an inner surface of the housing **200**. Referring also to FIG. **10**, screws **816** couple lugs **818** of the support assembly **812** to screw-receiving components **1006**, which extend from an underside surface **1010** of the seat **302**, to couple the support assembly **812** to the housing **200**. Other arrangements for coupling the connector support assembly to the housing **200** are also possible.

Referring still to FIGS. **8**, **9** and **10**, the connector support assembly **812** includes a support tray **1000**, a spring component **1002**, which is located in the support tray **1000**, and a pad **1004**, which is disposed between a base **1008** of the support tray **1000** and the spring component **1002**. The spring component **1002** includes tabs **820**, which mate with openings **822** in a front wall **824** of the support tray **1000** to generally fix the spring component **1002** relative to the support tray **1000**. Alternative arrangements for fixing the spring component **1002** in the support tray **1000** are possible including fasteners, such as screws, rivets or staples, glue, or other snap-in fastening arrangements. In addition, the spring component **1002** may be sized so that an interference fit is provided between the spring component **1002** and the connectors **806**, **808**.

The spring component **1002** includes passages **1100**, **1102** and **1104**, which are shown in FIG. **11**. The passages **1100**, **1102**, **1104** extend between a bottom end **1200** of the spring component **1002** to a top end **1202**. The passages **1100**, **1102** and **1104** receive first and second data connectors **806**, **808** and charging connector **810**, respectively. The charging connector **810** is movable in the z direction through the passage **1104** between a stowed position, which is shown in FIG. **8**, and an extended position, which is shown in FIG. **9**. The charging connector **810** is generally a floating connector that is biased toward the stowed position and moveable under a magnetic force to the extended position. Passage **1104**, which

receives the charging connector **810** and allows the charging connector **810** to slide relative thereto.

Collars **1018** are located at the top end **1202** of the spring component **1002** to surround the passages **1100**, **1102** and ribs **1012** extend from inner walls **1014** of the passages **1100**, **1102**. Contact surfaces **1204** of the collars **1018** abut the connectors **806**, **808** to limit translation of the connectors **806**, **808** in the x and y directions. The collars **1018** may fully or partially surround the connectors **806**, **808**.

Ribs **1012** extend from inner walls **1014** and **1016** of passages **1100** and **1102** of the spring component **1002**, respectively. The ribs **1012** contact the first and second data connectors **806**, **808** in order to maintain the connectors **806**, **808** in a starting position within the respective passages **1100**, **1102**. The spring component **1002** is biased toward a non-deformed shape, which is shown in FIG. **13**, or a slightly deformed state in which some deformation may occur in response to interference with the connectors **806**, **808**. An amount of movement of the connectors **806**, **808** relative to the connector support assembly **812** may be determined by one of both of a rigidity of the spring component **1002** and a size of the apertures **800** and **802**, respectively. The spring component **1002** facilitates independent movement of the connectors **806**, **808**, **810**. Elastic deformation due to a force being applied to one of the connectors is not transferred to the other connectors through the spring component **1002**.

The spring component **406** is made from a flexible material such as silicone rubber, urethane rubber or cork, for example. A hard plastic having flexible fingers may alternatively be used.

Because the mating connectors of the portable electronic device **100** are fixed relative to one another, additive tolerances may result in displacements in mating connector locations when compared to manufacturing specifications of the portable electronic device **100**. Additive tolerances are generally the sum of internal tolerances of each mating connector component, tolerances of components coupled the mating connector components and assembly process tolerances. The connector support assembly **812** compensates for the additive tolerances of the mating connectors of the portable electronic device **100** by providing a spring component **1002** that allows connectors **806**, **808** of the dock **150** to pivot in order to align with the mating connectors of the portable electronic device **100**. Because the connectors **806**, **808** are not fixed relative to the dock **150**, manufacturing of the dock **150** may be simplified because tolerances relating to connector location within the dock **150** may be relaxed compared to fixed connector docks.

The base **1008** of the support tray **1000** limits movement of the connectors **806**, **808** in the z-direction to facilitate coupling with mating connectors of the portable electronic device **100**. The pad **1004** is elastically deformable to accommodate some movement of the connectors **806** and **808** in the z direction. The pad **1004** may be interference fit with the connectors **806**, **808** to bias the connectors **806**, **808** toward the mating connectors of the portable electronic device **100** and absorb tolerances. The pad **1004** is biased toward a non-deformed shape, which is shown in FIG. **10**, and is compressible in response to a downward, or axial, force on the connector **806**, **808**. In one example, the pad **804** is two-shot or overmolded onto the support tray **1000** to reduce the part count of the dock **150**.

As shown in FIG. **11**, apertures **1106** extend through the pad **1004**. Referring also to FIG. **10**, the apertures **1106** are aligned with the through-hole leads of the connectors **806**, **808**, which protrude through an opposite surface of printed circuit boards (PCB), **1108**, **1110** of the first and second data connectors **806**, **808**, respectively. The apertures **1106** generally protect the leads and solder joints of the PCB **1108**, **1110** from stress during assembly and use when the portable electronic device **100** is inserted into and removed from the dock **150**.

Referring also to FIG. **14**, the support tray **1000** includes openings **1400**, which extend through a rear wall **1402** of the support tray **1000** to allow wiring **1404** of the connectors **806**, **808**, **810** to extend therethrough. The wiring **1404** may be flexible cables coupled between the connectors **606**, **608**, **610** and an electronic device (not shown), a multimedia device (not shown) and a power source (not shown), respectively. In one example, the flexible cables are coupled to a connector (not shown) that is mounted on a main PCB **1500** coupled inside the housing **200**, as shown in FIG. **15**. The flexible cables may alternatively be soldered to the main PCB **1500**. When a main PCB is not included, the flexible cables may be soldered, crimped or inserted into mating pins of one or more connectors. Cables for electrically communicating with the electronic device, multimedia device and power source may extend through opening **1502**.

In operation, a user visually and/or tactilely aligns mating connectors of the portable electronic device **100** with the connectors **806**, **808** and **810** of the dock **150** and then moves the mating connectors into engagement with the connectors **806**, **808**, **810**. When the mating connectors are not aligned with the connectors **806**, **808** in the x and/or y directions, a force is imparted on one or both of the connectors **806**, **808** by the portable electronic device **100**. The ribs **1012** of the spring component **1002** and the pad **1004** elastically deform in order to accommodate pivoting of the one or both of the connectors **806**, **808** in response to the force. Multiple forces may be applied to the connectors **806**, **808** in various different directions while the user attempts to join the connectors of the portable electronic device **100** and dock **150**. The charging connector **810** moves toward the mating charging connector of the portable electronic device **100** when the magnet of the mating charging connector is near the charging connector **810**. Once connected, the connectors **806**, **808** may return to the their starting positions or one or both of the connectors **806**, **808** may remain out of alignment with the starting position due to additive tolerances of the mating connectors of the portable electronic device **100**. Because the connectors **806**, **808** are able to pivot in order to align with the mating connectors, additive tolerance issues relating to more than one fixed mating connector are avoided.

Referring to FIG. **16**, in another example, the ribs **1012** include steps **1600**. Two or more steps **1600** are spaced along the length of the ribs **1012** to decrease a rib cross-sectional area between the top end **1202** and a bottom end **1200** of the spring component **1002**. When a mating connector of a portable electronic device **100** exerts a force on the connector **806**, **808**, in the x and/or y direction, a maximum compressive force is applied near the top end **1202** of the spring component **1002**. By providing a larger rib cross-sectional area near the top end **1202**, the amount of force that is transferred to the bottom end **1200** of the spring component **1002** is reduced. Therefore, damage to solder joints, for example, between the PCBs **1108**, **1110** and the connectors **806**, **808**, respectively, is less likely to occur. Similarly, stress resulting from any shifting, tilting or other alignment forces exerted by the mating connectors of the portable electronic device **100** is reduced.

The charging connector **810** may be replaced with a fixed connector that is mounted within the connector support assembly **812** in a similar manner as data connectors **806** and

808. Further, although three connectors are shown in the example of FIGS. 9 to 15, any number of connectors may be possible.

The connector support assembly and connector(s) may be provided as a single connector assembly that may be mounted in any dock. The connector support assembly may be manufactured to meet specifications associated with docks of different portable electronic devices.

Although the collar 1018 is shown as part of the spring component 1002, the collar 1018 may alternatively form part of the seat 302. In another example, the spring component 1002 does not include a collar 1018. In this example, both translation in the x and y directions and pivoting of the connectors 806, 808 relative to the housing 200 are possible.

The dock 150 described herein may realize one or more advantages, some of which have already been described. The dock 150 facilitates quick and easy connection of a portable electronic device thereto. By compensating for some misalignment between connectors of the dock 150 and mating connectors of the portable electronic device, damage resulting from stress on both the portable electronic device 100 and the dock 150 normally associated with connection and removal operations, may be avoided. Further, the life of the dock 150 may be extended because entry of dust and dirt into the dock 150 is limited by the collar, which may act as a seal.

The above-described embodiments are intended to be examples only. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope of the present application, which is defined solely by the claims appended hereto.

What is claimed is:

1. A dock for receiving a portable electronic device, comprising:
- a housing comprising an aperture;
- a support coupled to an inner wall of the housing, a portion of the support being elastically deformable;
- a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device; and
- a collar abutting the connector within the housing to limit translation of the connector, the connector being pivotable relative to the collar;
- wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.

2. A dock as claimed in claim 1, wherein the support includes a spring component received in a support tray, the spring component being elastically deformable.

3. A dock as claimed in claim 2, wherein the spring component comprises a passage for receiving the connector, the passage comprising ribs for contacting the connector.

4. A dock as claimed in claim 2, wherein the spring component biases the connector to a starting position within the passage.

5. A dock as claimed in claim 2, wherein the spring component comprises three passages for receiving a first data connector, a second data connector and a charging connector.

6. A dock as claimed in claim 1, wherein the collar surrounds the connector at a location adjacent the aperture.

7. A dock as claimed in claim 1, comprising more than one connector, each connector being independently movable relative to the housing.

8. A dock as claimed in claim 1, wherein the housing comprises a seat for receiving the portable electronic device and the aperture extends through the seat.

9. A dock as claimed in claim 1, wherein the connector is a micro HDMI connector.

10. A dock as claimed in claim 1, wherein the connector is a micro USB connector and the wiring receives data from an electronic device.

11. A dock as claimed in claim 1, wherein the connector is a charging connector.

12. A dock for receiving a portable electronic device, comprising:
- a housing comprising an aperture;
- a support coupled to an inner wall of the housing, the support comprising a spring component received in a support tray, the spring component comprising a passage for receiving the connector, the passage comprising ribs for contacting the connector, the spring component being elastically deformable in response to non-axial movement of at least a portion of the connector; and
- a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device;
- wherein a cross-sectional area of the ribs is reduced between a top end of the spring component and a bottom end of the spring component, the top end being located adjacent the aperture of the housing.

13. A dock for receiving a portable electronic device, comprising:
- a housing comprising an aperture;
- a support coupled to an inner wall of the housing, a portion of the support being elastically deformable;
- a pad disposed in the support and elastically deformable in response to axial movement of the connector; and
- a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device;
- wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.

14. A connector assembly for a dock, the connector assembly comprising:
- a support for coupling to an inner wall the dock, the support comprising a spring component received in a support tray, the spring component comprising a passage, the spring component being elastically deformable; and
- a connector received in the support and extending through the passage for electrically communicating with a portable electronic device received by the dock, wiring of the connector for transferring data from the portable electronic device;
- wherein the passage comprises ribs for contacting the connector and a cross-sectional area of the ribs is reduced between a top end of the spring component and a bottom end of the spring component, the top end being located adjacent the aperture of the housing.

15. A connector assembly for a dock, the connector assembly comprising:
- a support for coupling to an inner wall the dock, the support comprising a collar, a portion of the support being elastically deformable; and
- a connector received in the support for electrically communicating with a portable electronic device received by the dock, wiring of the connector for transferring data from the portable electronic device;
- wherein the portion of the support elastically deforms in response to non-axial translation and pivoting relative to the collar of at least a portion of the connector.

16. A connector assembly as claimed in claim **15**, wherein the support includes a spring component received in a support tray, the spring component being elastically deformable.

17. A connector assembly as claimed in claim **16**, wherein the spring component comprises a passage for receiving the connector, the passage comprising ribs for contacting the connector.

18. A connector assembly as claimed in claim **15**, wherein the spring component biases the connector to a starting position within the passage.

19. A connector assembly as claimed in claim **15**, comprising a collar abutting the connector within the housing to limit translation of the connector.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,545,247 B2
APPLICATION NO. : 13/397486
DATED : October 1, 2013
INVENTOR(S) : Leonardo Aldana 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 the Claims:

Column 9, line 54, claim 4, delete “claim 2” and insert therefor -- claim 3 --.

Signed and Sealed this
Third Day of June, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,545,247 B2
APPLICATION NO. : 13/397486
DATED : October 1, 2013
INVENTOR(S) : Leonardo Aldana 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 the Claims:

Column 11, line 8, claim 18, delete “claim 15” and insert therefor -- claim 17 --

Signed and Sealed this
Twelfth Day of August, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

EXHIBIT E

US007529305B1

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

(10) **Patent No.: US 7,529,305 B1**
(45) **Date of Patent: May 5, 2009**

(54) **COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING**

(75) Inventors: **Wen Tong**, Ottawa (CA); **Michail G. Bakulin**, Kirova (RU); **Vitaly B. Kreyndelin**, Moscow (RU); **Alexander M. Shloma**, Gagarina (RU); **Yuriy S. Shinakov**, Moscow (RU)

(73) Assignee: **Nortel Networks Limited**, St. Laurent, Quebec (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 887 days.

(21) Appl. No.: **10/399,859**

(22) PCT Filed: **Oct. 27, 2000**

(86) PCT No.: **PCT/RU00/00426**

§ 371 (c)(1),
(2), (4) Date: **Aug. 29, 2003**

(87) PCT Pub. No.: **WO02/35762**

PCT Pub. Date: **May 2, 2002**

(51) **Int. Cl.**
H04K 1/10 (2006.01)

(52) **U.S. Cl.** **375/260**; 375/267; 375/295; 375/299; 455/101; 455/103

(58) **Field of Classification Search** 375/267, 375/260, 295, 299
See application file for complete search history.

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Ben Lu; et al.; Iterative Receivers for Multiuser Space-Time Coding Systems; IEEE International Conference on Communications, Jun. 18-22, 2000, pp. 302-306, XP002174379.

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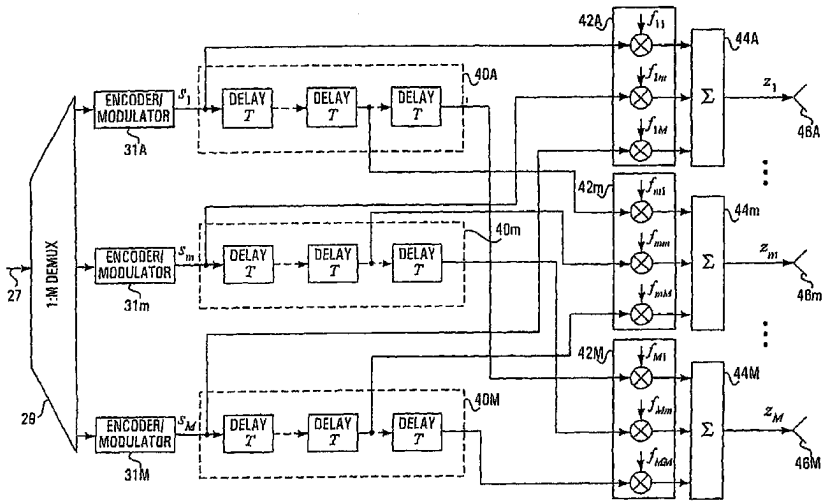
Primary Examiner—Chieh M Fan
Assistant Examiner—Siu M Lee

(57) **ABSTRACT**

It is proposed to combine space-time coding and spatial multiplexing. Also, the use of orthogonal transformation matrices is proposed, which ensures that each bistream contributes to the signal on each antenna.

12 Claims, 8 Drawing Sheets



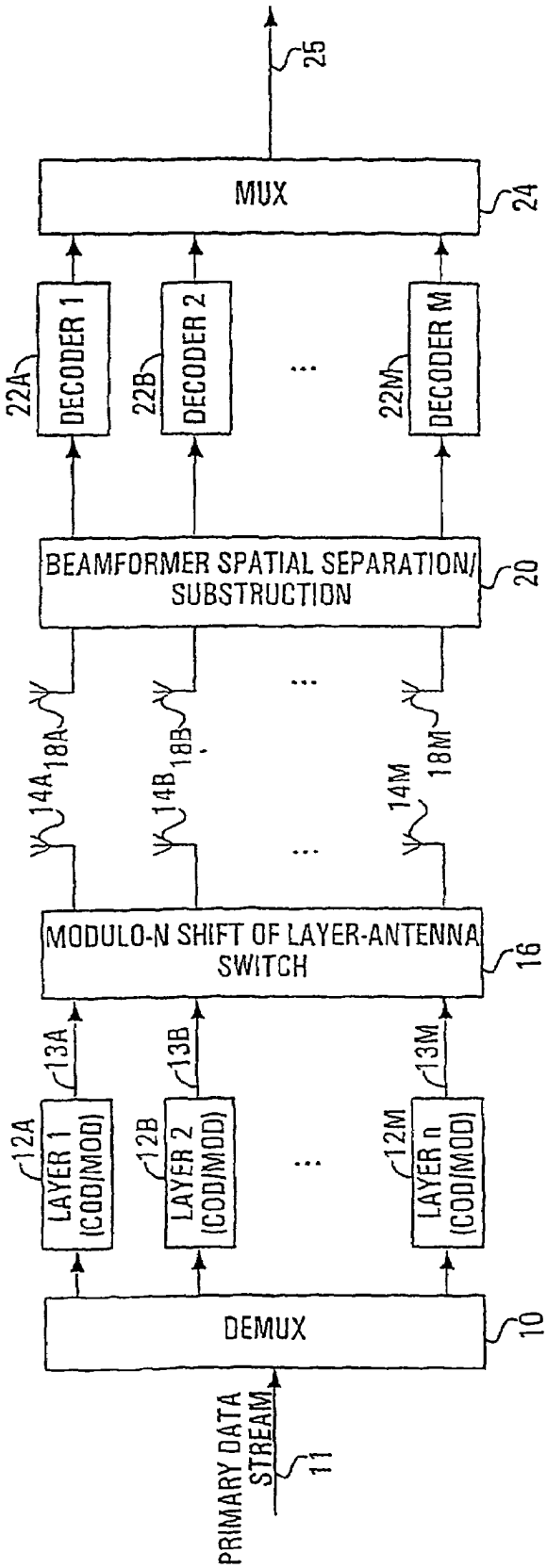
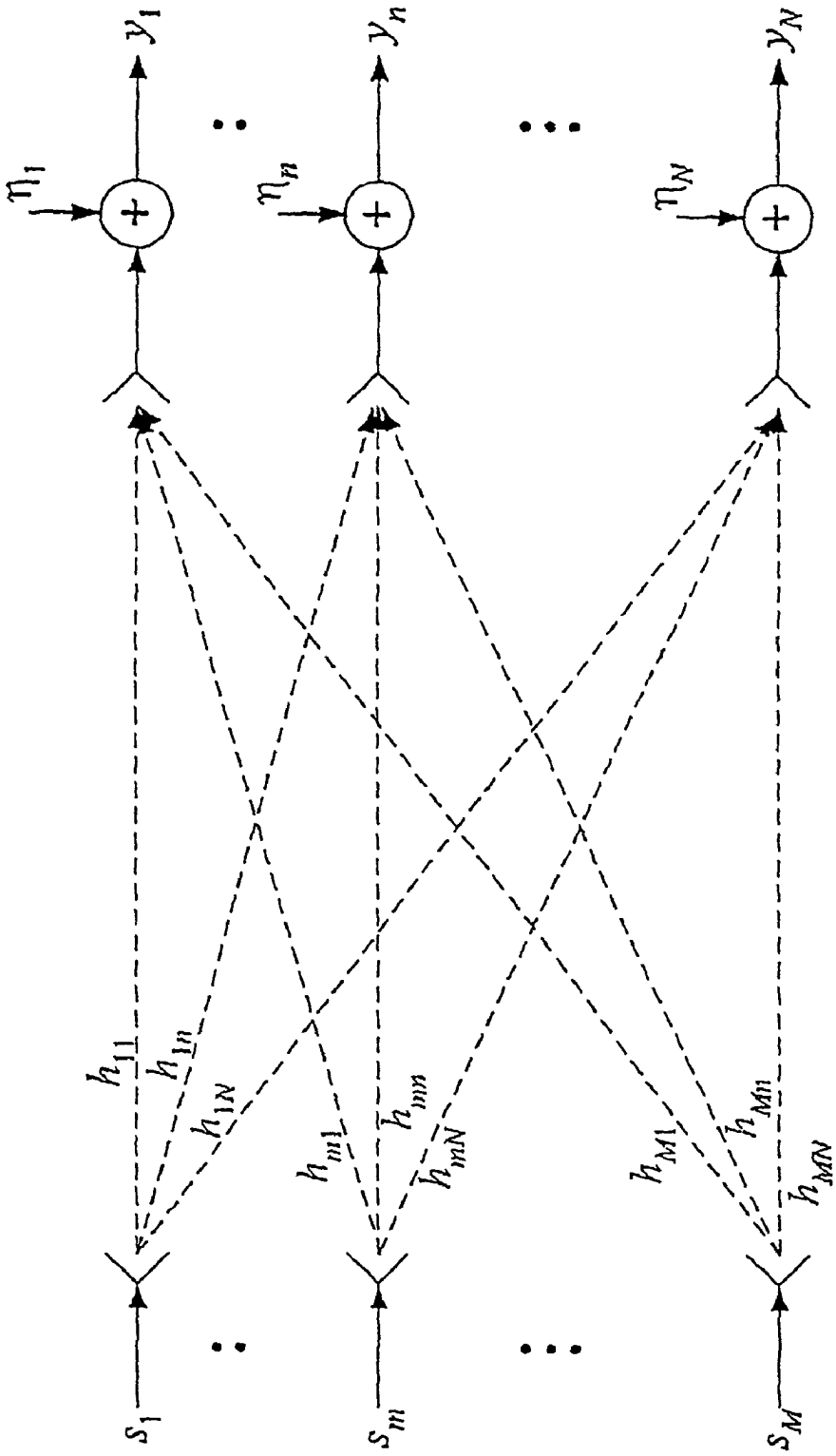


FIG. 1
PRIOR ART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y_n
y_N
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η_N
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h_{1N}
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s_1
s_m
s_M

FIG. 2

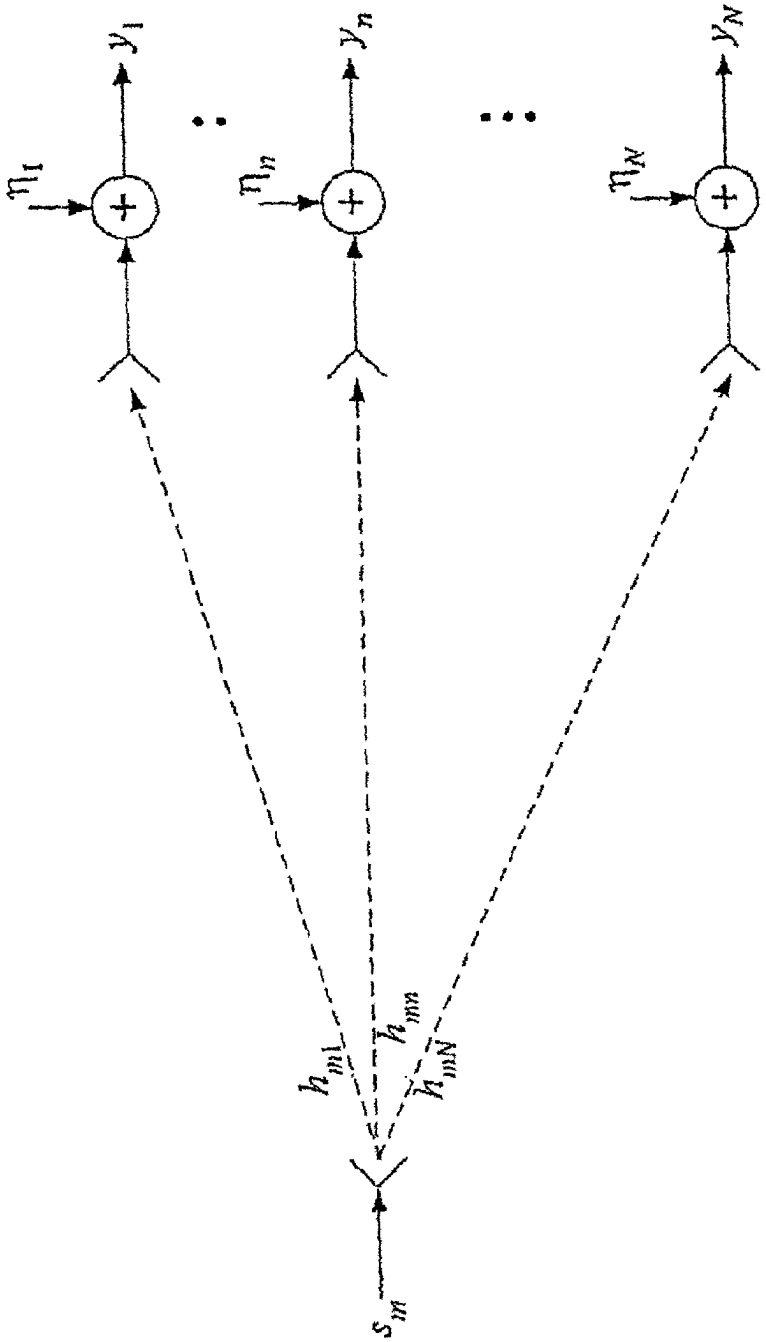


FIG. 3

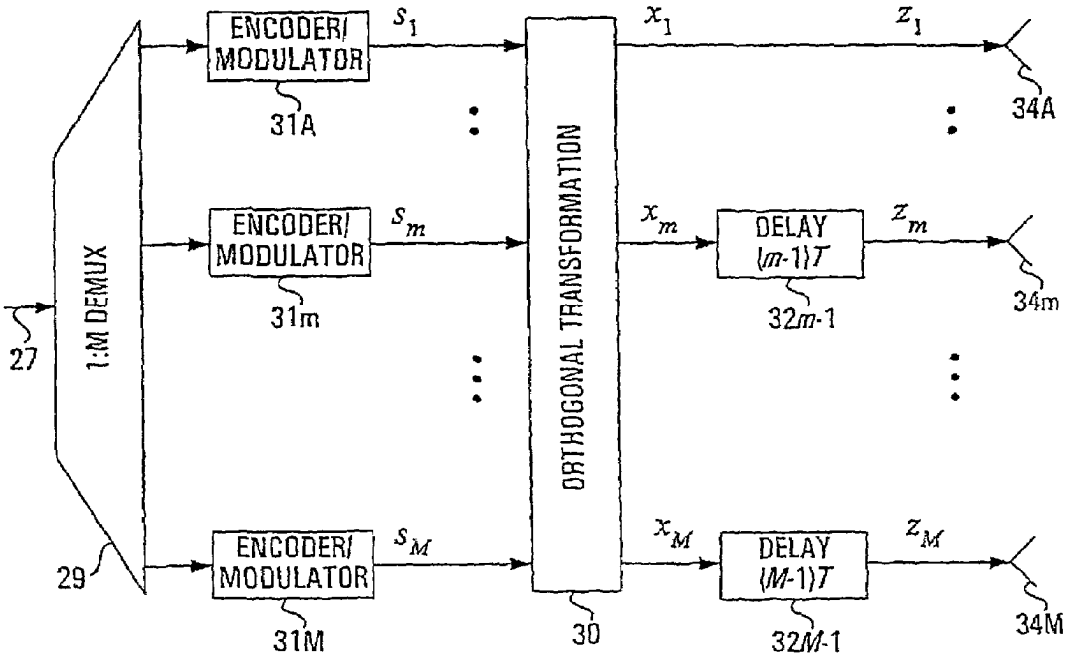
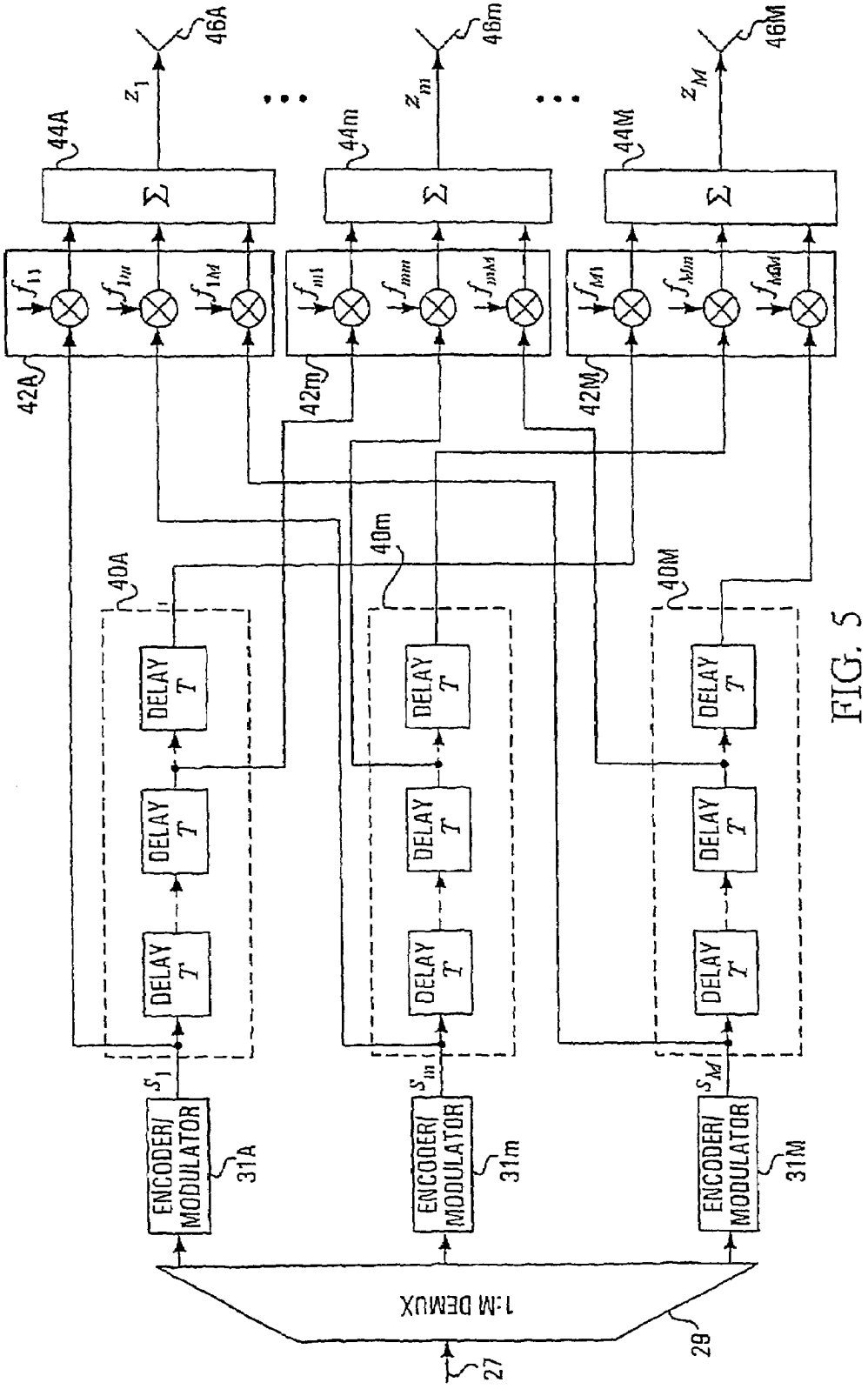

ENCODER/ MODULATOR
31A
ENCODER/ MODULATOR
31m
ENCODER/ MODULATOR
31M
1:M DEMUX
27
29
s_1
s_m
s_M
ORTHOGONAL TRANSFORMATION
30
x_1
x_m
x_M
DELAY (m-1)T
32m-1
DELAY (M-1)T
32M-1
z_1
z_m
z_M
34A
34m
34M

FIG. 4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z_m
z_M
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44M
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f_{mm}
f_{mM}
f_{M1}
f_{Mm}
f_{MM}
42A
42m
42M
40A
40m
40M
DELAY T
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ENCODER/ MODULATOR
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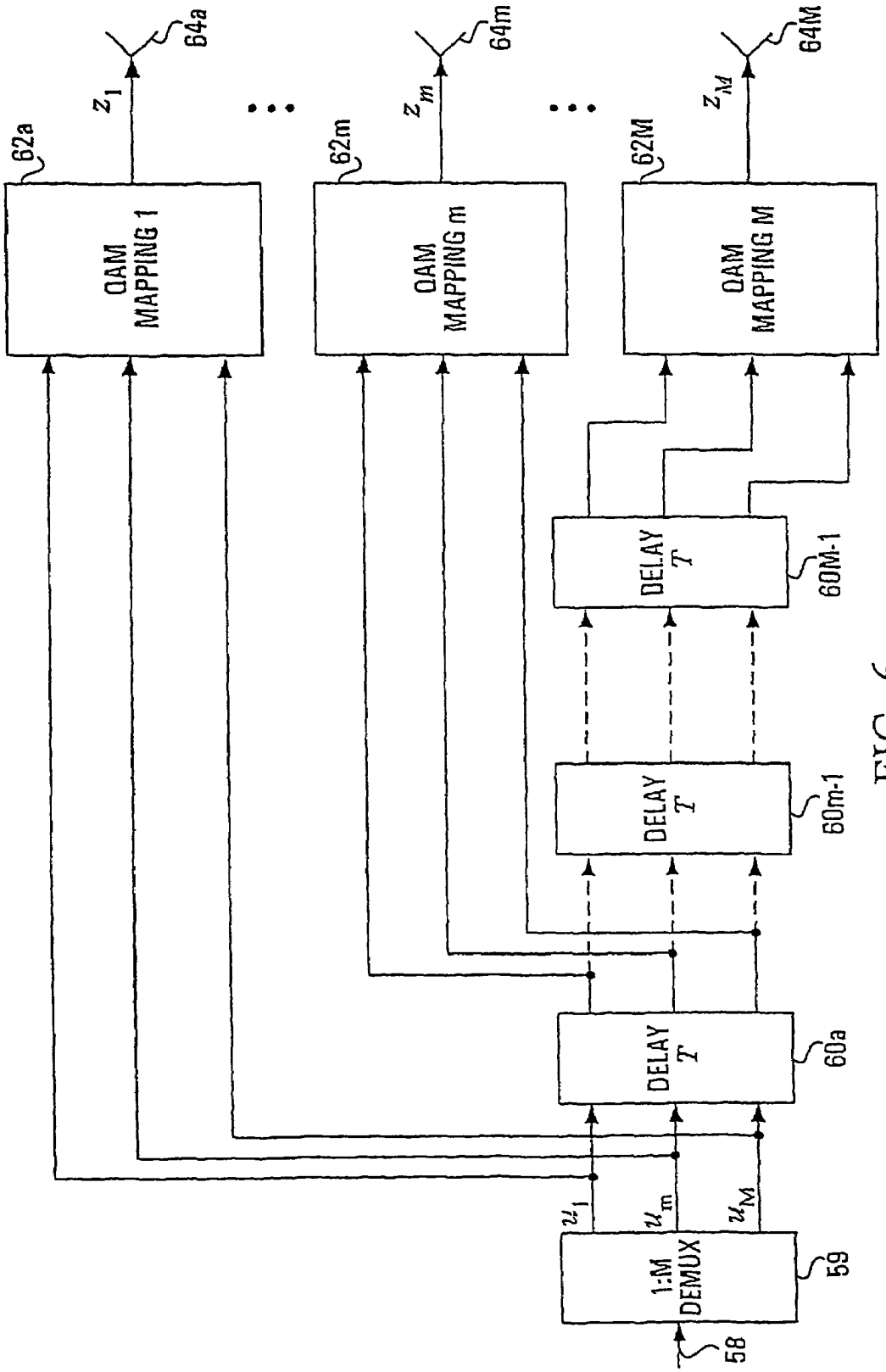
31M
1:M DEMUX
27
29

FIG. 5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z_m
z_M
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62m
62M
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OAM MAPPING m
OAM MAPPING M
DELAY T
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DELAY T
60m-1
DELAY T
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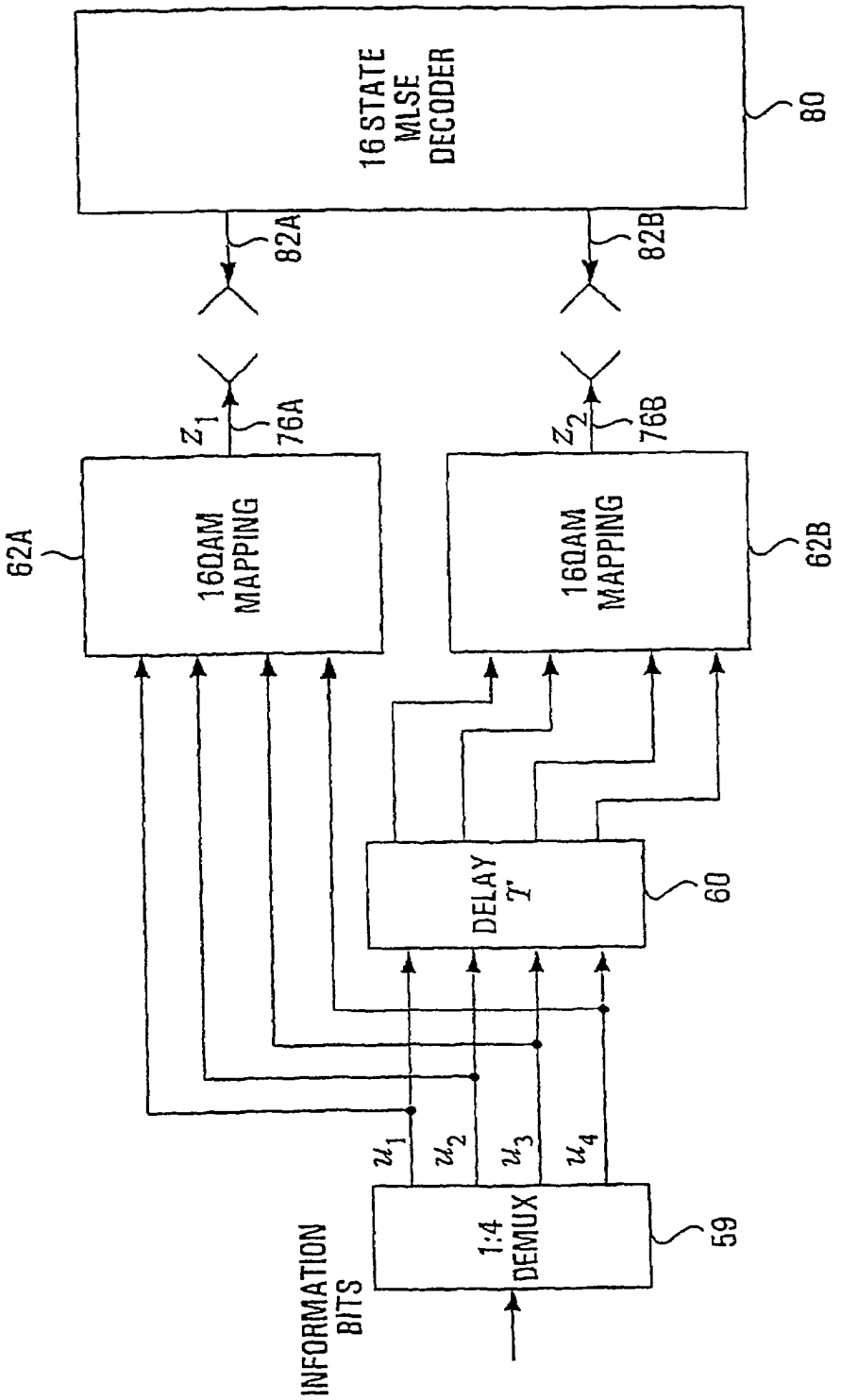
u_m
u_M
1:M DEMUX
59
58

FIG. 6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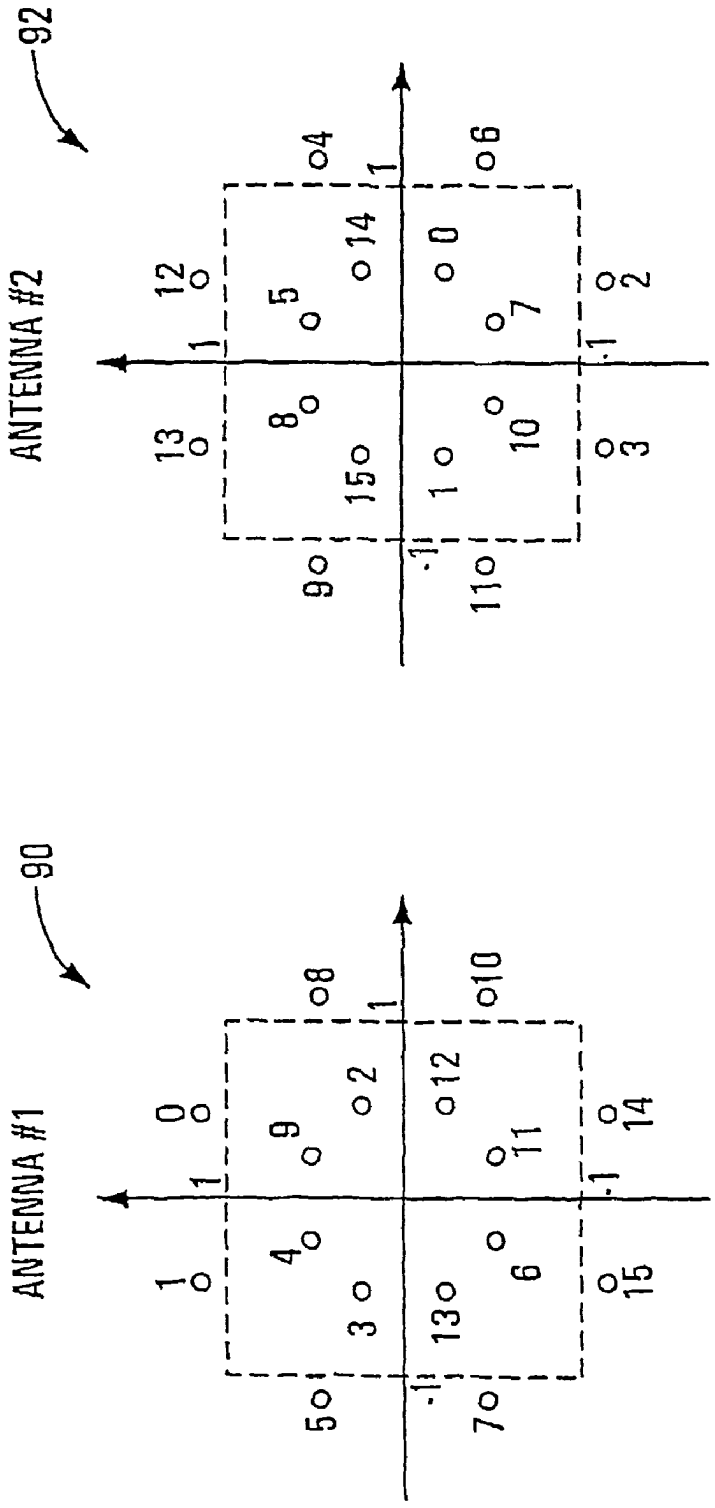
82B
z_1
76A
z_2
76B
16QAM MAPPING
62A
16QAM MAPPING
62B
DELAY T
60
u_1
u_2
u_3
u_4
1:4 DEMUX
59
INFORMATION BITS

FIG. 7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1
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1
9
11
-1
90
ANTENNA #1
8
1
10
0
2
12
14
9
11
1
1
4
6
15
3
13
-1
5
7

FIG. 8

COMBINATION OF SPACE-TIME CODING AND SPATIAL MULTIPLEXING, AND THE USE OF ORTHOGONAL TRANSFORMATION IN SPACE-TIME CODING

FIELD OF THE INVENTION

The invention relates to systems and methods for performing layered space-time coding for wireless channels.

BACKGROUND OF THE INVENTION

With the explosion in the demand for wireless Internet services, a number of competing solutions have been developed. UMTS (Universal Mobile Terrestrial Service) standardization has lead to the 3 Gpp standard which offers a 2 Mbps data rate per sector. Work is underway on HSPDA (high speed data access), a higher speed packet data access variation. IS-2000, an evolution of IS-95 provides HDR (High Speed Data Rate) and 1XEV (1X Evolution) which allow wireless Internet browsing at a rate of 7.2 Mbps per sector. Notwithstanding these solutions, there is still the demand to push rates higher.

Recently, it has been proposed to use BLAST (Bell Labs Layered Space Time) which is a layered space-time coding approach, as a wireless data solution. Referring to FIG. **1**, the basic concept behind this layered space-time coding approach involves, at the transmit side, a demultiplexer **10** which demultiplexes a primary data stream **11** into M data substreams of equal rate. Each of the M data streams is then encoded and modulated separately in respective coding/modulating blocks **12** (**12**A, **12**B, . . . , **12**M) to produce respective encoded and modulated streams **13** (**13**A, **13**B, . . . , **13**M). There are M transmit antennas **14** (**14**A, **14**B, . . . , **14**M). A switch **16** periodically cycles the association between the modulated streams **13**A, **13**B, . . . , **13**M and the antennas **14**A, **14**B, . . . , **14**M. At the receive side, there are M antennas **18** (**18**A, **18**B, . . . , **18**M) which feed into a beamforming/spatial separation/substruction block **20** which performs a spatial beamforming/nulling (zero forcing) process to separate the individual coded streams and feeds these to respective individual decoders **22** (**22**A, **22**B, . . . , **22**M). The outputs of the decoders **22**A, **22**B, . . . , **22**M are fed to a multiplexer **24** which multiplexes the signals to produce an output **25** which is an estimate of the primary data stream **11**.

There are a number of variations on this architecture. One is to modify the receiver antenna pre-processing to carry out MMSE (minimum mean square error) beamforming rather than nulling in order to improve the wanted signal SNR (signal-to-noise ratio) at the expense of slightly increased ISI (inter-symbol interference). Both the MMSE and nulling approaches normally have the disadvantage that some sort of diversity of the receiver antenna array is necessarily sacrificed in the beamforming process. In order to overcome this problem, layering of the receiver processing can be employed such that after the strongest signal has been decoded (typically using the Viterbi MLSE (maximum likelihood sequence estimation) algorithm) it is subtracted from the received antenna signals in order to remove the strongest signal. This process is iterated down until detection of the weakest signal requires no nulling at all, and its diversity performance is therefore maximized. A disadvantage with this layered approach is the same as that with all subtractive multi-user detection schemes, that the wrong subtraction can cause error propagation.

There are several types of layered space-time coding structures, including horizontal BLAST (H-BLAST), diagonal BLAST (D-BLAST) and vertical BLAST. They have identical performance for both optimal linear and non-linear receivers, assuming error control coding is not used in such systems. For optimal linear reception (linear maximum likelihood), these structures have the same SNR performances as those with only a single transmit antenna and a single receive antenna, but do offer the advantage of improved spectral efficiency.

In order to achieve this improved spectral efficiency, in such systems it would be advantageous to have a large number of transmit and receive antennas, for example four of each. However, while this may be practical for larger wireless devices such as laptop computers, it is impractical for smaller hand-held devices because it is not possible to get the antennas far enough apart to ensure their independence. Because of this, for hand-held devices, a practical limit might be two transmit and two receive antennas. Also, another factor limiting the practical number of antennas is cost. Typically about two thirds of the cost of a base station transceiver is in the power amplifier plus antennas, and this will increase if more antennas are added. These factors make only a two by two system commercially practical.

By way of example, consider a system with M transmit and N receive antennas in a frequency non-selective, slowly fading channel. The sampled baseband-equivalent channel model is given by

$$Y=HS+\eta$$

where $H\epsilon C^{N\times M}$ is the complex channel matrix with the (i,j)-th element being random fading between the i-th receive and j-th transmit antenna. $\eta\epsilon C^{N}$ is the additive noise source and is modelled as a zero mean circularly symmetric complex Gaussian random vector with statistically independent elements, that is $\eta\sim CN(0,2_{\eta}{}^{2}I_{N})$. The i-th element of $S\epsilon C^{M}$ is the symbol transmitted at the i-th transmit antenna and that of $Y\epsilon C^{N}$ is the symbol received at the i-th received antenna. The model is shown in FIG. **2**.

That such a system has no improvement in SNR performance can be explained by noting that the data symbol s_m is transmitted only by one antenna, and in case of full cancellation of other transmit antennas, the model of such a system is shown in FIG. **3**. In this case there is one transmit antenna and N receive antennas. Therefore, for symbol S_m there is no coding gain.

It would be advantageous to have a layered space-time coding structure which provides the improved spectral efficiency, but which also provides improved SNR performance.

SUMMARY OF THE INVENTION

Embodiments of the invention provide coding gain systems and methods which feature combined space-time coding and spatial multiplexing, and transmitters adapted to include such functionality. The space-time coding introduces a coding gain, and makes symbols more immune to fading since each information component is represented somehow in each spatial output. In some embodiments, the space-time coding comprises a layered space-time architecture. Advantageously, these solutions are amenable to implementation with two transmit antennas and two receive antennas, a configuration suitable for hand-held devices.

According to one broad aspect, the invention provides a coding gain system adapted to transmit a plurality M of symbol substreams. The coding gain system has a space-time coding function adapted to produce M space-time coded streams, with each symbol of the M symbol substreams being represented in all M space-time coded streams and at different

times. In some embodiments, the coding gain system provided by the invention can be considered to include M transmit antennas each adapted to transmit a respective one of the M space-time coded streams, and/or demultiplexing and encoding functionality adapted to produce the M symbol substreams from a primary input stream.

In some embodiments, the space-time coding function has an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams, and has delay elements adapted to insert delays in the M orthogonal outputs to produced M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time. For example, the delay elements can be adapted to introduce a delay of m−1 symbol periods in the mth orthogonal output, where m=1, . . . , M.

In another embodiment, the space-time coding function has delay elements adapted to insert a delay of M−1 symbol periods in each of the M substreams, and an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in the delay elements by m−1 symbol periods.

In some embodiments the M substreams are non-binary symbols. In other embodiments the M substreams are bit streams. In these embodiments, the orthogonal transform comprises orthogonal symbol mappings, for example M 2^M QAM or MPSK mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth 2^M QAM mapping function being a function of the M substreams delayed in said delay elements by m−1 bit periods.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described with reference to the attached drawings in which:

FIG. **1** is a block diagram of a known space-time coding system;

FIG. **2** is a channel model for the system of FIG. **1**;

FIG. **3** is a channel model for a single antenna output of the system of FIG. **1**;

FIG. **4** is a block diagram of a transmitter featuring a coding gain system provided by an embodiment of the invention;

FIG. **5** is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

FIG. **6** is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention;

FIG. **7** is a block diagram of a transmitter featuring a coding gain system provided by another embodiment of the invention; and

FIG. **8** is a constellation diagram for the 16 QAM Gray mappings of FIG. **7**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the invention provide a layered space-time architecture with additional gain provided with space-time coding. To achieve this each information symbol s_m is arranged to as to be represented on all M Transmit Antennas. An algorithm of space-time coding is developed for one transmitter, and aggregated with algorithms for M transmitters, so that the spectral efficiency expected for conventional BLAST architecture is retained.

A range of coding gain methods/systems and transmitters are provided which combine space time coding and spatial multiplexing. Referring firstly to FIG. **4**, shown is a space-time coder/multiplexer coding gain system consisting of a 1:M demultiplexer **29** having a single primary input **27** and having M outputs which are each coded and modulated in respective encoder/modulator blocks **31**A, . . . , **31**M to produce encoded substreams $s_1, s_2, \ldots, s_M$. There is an orthogonal transformation block **30** and a number of delay blocks **32** (only two shown, **32***m*−1, **32**M−1) the outputs of which are connected to respective transmit antennas **34**A, . . . , **34**M. The orthogonal transformation block **30** has as its inputs the M encoded and modulated substreams $s_1, s_2, \ldots, s_M$. The orthogonal transformation block **30** performs the following matrix transform on the input substreams at each symbol interval:

$$X=FS,$$

where $S=(s_1, s_2, \ldots s_M)$ at a given instant, $X=(x_1, x_2, \ldots, x_M)\epsilon C^M$ is the output of the orthogonal transformation block **30**; and $F\epsilon C^{M\times M}$ is a complex matrix defining the orthogonal transformation. In one embodiment, the (i,m)-th element of F is defined by:

$$f_{im}=(\mathrm{Had}(i,m)\cdot e^{j(\pi(ml))/(2M)})/(\sqrt{M}),$$

where Had(i,m)ϵ(1; −1) is the (i,m)-th element of the Hadamard matrix. For M=2 this matrix is

$$F=\frac{1}{\sqrt{2}}\begin{bmatrix}1 & e^{j\pi/4}\\ 1 & -e^{j\pi/4}\end{bmatrix}.$$

However, this transformation matrix is not unique, this being only an example of a suitable orthogonal transformation. The optimization and/or search for the best of transformation matrix depends on the modulation for initial symbols s_m and on the number of antennas M. It is important that each output of the orthogonal transformation be a function of all the instantaneous inputs. In other words, $x_1=f_1(s_1, s_2, \ldots, s_M), \ldots, x_m=f_m(s_1, s_2, \ldots, s_M)$.

Now, to achieve the separation in time, the mth orthogonal transformation output xm is delayed by a time period equal to (m−1)T, where T is the symbol duration, such that the first output x_1 experiences no delay, and the Mth output x_M experiences a delay of (M−1)T. The output of the delay blocks **32** consists of the symbols $z_1, \ldots, z_M$ to be transmitted on the antennas **34**. The effect of the orthogonal transformation **30** plus the delay blocks **32** is that the mth input symbol s_m is represented in all m output streams, but at different times.

Referring now to FIG. **5**, another embodiment of the invention is provided in which the encoded and modulated symbols s_m are fed through respective delay banks **40** (**40**A, . . . , **40**M) each containing M−1 delay elements. Each symbol with equal delay is fed to a common scaling block **42**. Thus, all undelayed symbols $s_1, \ldots, s_M$ are fed to a first scaling block **42***a*, the symbols $s_1, \ldots, s_M$ delayed by (m−1)T are fed to an mth scaling block **42***m* and so on. Each scaling block **42***m* multiplies each of its inputs by a respective complex multiplier, and the results are summed in a respective summer **44***m* the output of which is the mth transmitted symbol z_m. This is really mathematically equivalent to the embodiment of FIG. **4** in that each output symbol z_m is again a function of all of the input symbols at a given instant, but at different times. Effectively, the delay block and the orthogonal transformation functions have been done in reverse order.

Both the examples of FIGS. **4** and **5** perform symbol level space-time encoding in the sense that the input to the space-time encoding process consists of symbols output by the encoder/modulator blocks. Referring now to FIG. **6**, another embodiment of the invention is provided in which bit-level space-time encoding is performed. In this embodiment, a 1:M demultiplexer **59** produces from an input bit stream **58** M bit substreams $u_1, \ldots, u_M$ which are all fed into delay elements **60**A, . . . , **60**M−1 each adding a further bit period T delay. The undelayed bits $u_1, \ldots, u_M$, and the bits output by each of the delay elements **60**A, . . . , **60**M−1 are fed to respective symbol mapping functions **62***a*, . . . **62**M which in the illustrated embodiment are QAM functions. Each QAM mapping function **62**A, . . . , **62**M maps its M input bits to a corresponding output symbol z_m which is output by corresponding antennas **64**A, . . . , **64**M. In one embodiment, the QAM mappings are designed such that they are orthogonal to each other.

Referring now to FIG. **7** a specific example of the embodiment of FIG. **6** is shown which is a very practical embodiment, and in which the same numbering scheme as FIG. **6** is used. In this case, it is assumed that the demultiplexer **59** is a 1:4 demultiplexer which produces four bit substreams u_1, u_2, u_3, u_4 which are all fed undelayed to a first 16 QAM mapping **62**A, and are all fed to a delay element **60** which introduces a delay T into the substreams and outputs the delayed substreams into a second 16 QAM mapping **62**B. The two QAM mappings **62**A, **62**B have outputs z_1, z_2 fed to respective transmit antennas **64**A, **64**B. Details of an example receiver are shown in which there is a 2^M state MLSE decoder **80** connected to two receive antennas **82**A, **82**B. It is to be understood that many different receiver structures can be used, and this is not important to the invention. This implementation lends itself to efficient implementation in handheld devices because there are only two transmit and two receive antennas.

A recommended mapping for the 16 QAM mapping functions **62**A, **62**B is shown in FIG. **8**. A first mapping is shown for the first antenna **64**A, generally indicated by **90**. A second mapping is shown for the second antenna **64**B, generally indicated by **92**. Each mapping shows how the 16 16QAM constellation points, defined by their position on the horizontal (real) and vertical (imaginary) axes, map to corresponding decimal versions (0 to 15) of input bit combinations u_1, u_2, u_3, u_4 (0000 to 1111).

In one example above, the receiver is a 2^M state MLSE decoder. As indicated previously, the particular receiver design is not important. It may be a Viterbi decoder, an iterative decoder, or some other type of decoder.

In the above embodiments, for symbol level space-time coding, it is assumed that the input to the space-time functionality consists of encoded and modulated symbol streams. In another embodiment, the encoding and modulation is integrated with the space-time coding.

Numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practised otherwise than as specifically described herein.

We claim:

1. A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:

a space-time coding block adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein the transmitter comprises a delay arrangement, arranged such that for each symbol of the M symbol substreams a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.

2. A transmitter according to claim **1** further comprising a demultiplexing and encoding block comprising a demultiplexer having M outputs, and M encoder/modulators each producing a respective one of the M symbol substreams, with each of the M encoder/modulators connected to receive a respective one of the demultiplexer outputs.

3. A transmitter according to claim **2** wherein the demultiplexing and encoding block is adapted to produce the M symbol substreams from an input stream.

4. A transmitter according to claim **3** wherein the space-time coding block comprises:

an orthogonal transform adapted to produce M orthogonal outputs each of which is a function of the M substreams;

wherein the delay arrangement comprises delay elements adapted to insert a respective different delay in M−1 of the M orthogonal outputs to produce the M space-time coded streams.

5. A transmitter according to claim **4** wherein the delay elements are adapted to introduce a delay of m−1 symbol periods in the mth orthogonal output, where m=1, . . . , M.

6. A transmitter according to claim **1** wherein the delay arrangement comprises:

delay elements adapted to insert a delay in at least one of the M substreams; and

the space-time coding function further comprises an orthogonal transform adapted to produce M orthogonal outputs, with the mth orthogonal output being a function of the M substreams delayed in said delay elements by m−1 symbol periods.

7. A transmitter according to claim **6** wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the mth M-ary mapping function being a function of the M substreams delayed in said delay elements by m−1 bit periods.

8. A method comprising:

demultiplexing an input symbol stream into M symbol substreams;

performing coding and modulation on each of said M symbol substreams;

performing a space-time coding function adapted to produce M space-time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams, wherein each symbol of the M symbol substreams is represented in all M space-time coded streams, wherein performing the space-time coding function comprises implementing a delay function, arranged such that-for each symbol of the M symbol substream, a time of representation of the symbol in the M space-time coded streams is different for each of the

M space-time coded streams, each space-time coded symbol comprising a representation of a symbol of each of the M symbol substreams;

transmitting the M space-time coded streams on respective antennas, such that for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.

9. A method according to claim **8** wherein performing the space-time coding function comprises:

executing an orthogonal transform to produce M orthogonal outputs each of which is a function of the M substreams; and

implementing the delay function comprises delaying the M orthogonal outputs to produce M delayed orthogonal outputs such that each of the M delayed orthogonal outputs is a function of a given element of each of the M substreams at a different time.

10. A method according to claim **9** wherein the mth orthogonal output is delayed by m−1 symbol periods, where m=1, . . . , M.

11. A method according to claim **8** wherein performing the space-time coding function comprises:

delaying at least one of the M substreams

executing an orthogonal transform adapted to produce M orthogonal outputs, with the m^{th} orthogonal output being a function of the M substreams delayed m−1 symbol periods.

12. A method according to claim **11** wherein the M substreams are bit streams, and wherein the orthogonal transform comprises M M-ary mapping functions, each adapted to produce a respective sequence of M-ary symbols with the M-ary symbol of the m^{th} M-ary mapping function being a function of the M substreams delayed in said delay elements by m−1 bit periods.

* * * * *

EXHIBIT F

US009313065B2

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

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(45) **Date of Patent: *Apr. 12, 2016**

(54) **SCATTERED PILOT PATTERN AND CHANNEL ESTIMATION METHOD FOR MIMO-OFDM SYSTEMS**

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This patent is subject to a terminal disclaimer.

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(58) **Field of Classification Search**
CPC H04B 7/04; H04B 7/0684; H04B 7/0413; H04L 1/0618; H04L 5/0023; H04L 5/0048; H04L 25/022; H04L 27/2627
See application file for complete search history.

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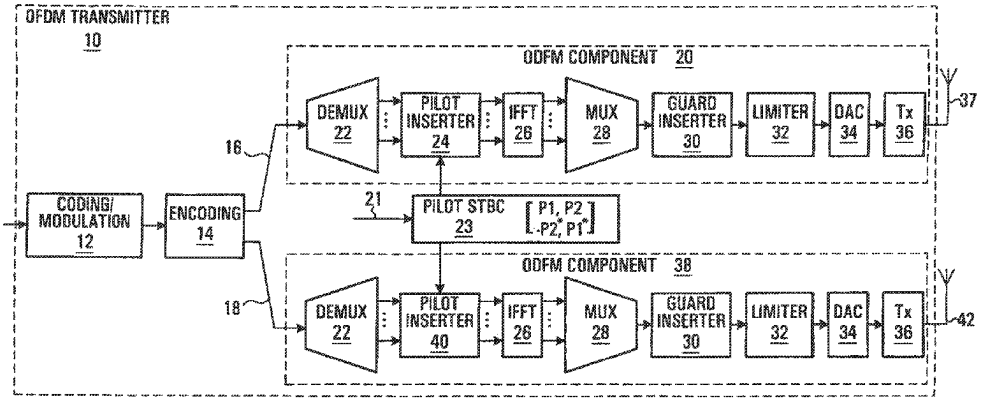
(57) **ABSTRACT**

A method and apparatus are provided for reducing the number of pilot symbols within a MIMO-OFDM communication system, and for improving channel estimation within such a system. For each transmitting antenna in an OFDM transmitter, pilot symbols are encoded so as to be unique to the transmitting antenna. The encoded pilot symbols are then inserted into an OFDM frame to form a diamond lattice, the diamond lattices for the different transmitting antennae using the same frequencies but being offset from each other by a single symbol in the time domain. At the OFDM receiver, a channel response is estimated for a symbol central to each diamond of the diamond lattice using a two-dimensional interpolation. The estimated channel responses are smoothed in the frequency domain. The channel responses of remaining symbols are then estimated by interpolation in the frequency domain.

42 Claims, 7 Drawing Sheets



Related U.S. Application Data

continuation of application No. 13/586,660, filed on Aug. 15, 2012, now Pat. No. 8,406,118, which is a continuation of application No. 12/468,624, filed on May 19, 2009, now Pat. No. 8,254,246, which is a continuation of application No. 11/819,690, filed on Jun. 28, 2007, now Pat. No. 7,545,734, which is a continuation of application No. 10/038,883, filed on Jan. 8, 2002, now Pat. No. 7,248,559.

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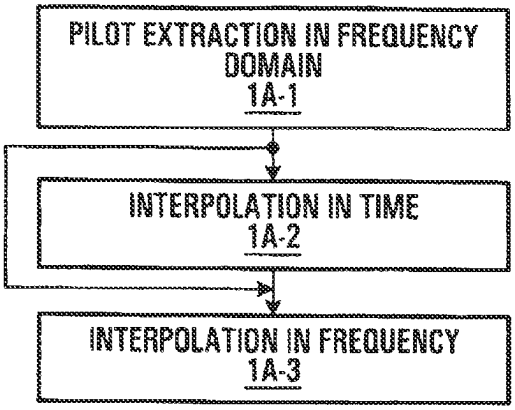


FIG. 1A
(PRIOR ART)

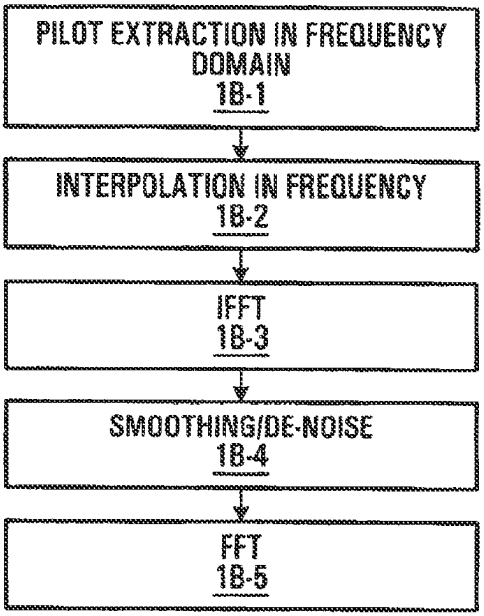


FIG. 1B
(PRIOR ART)

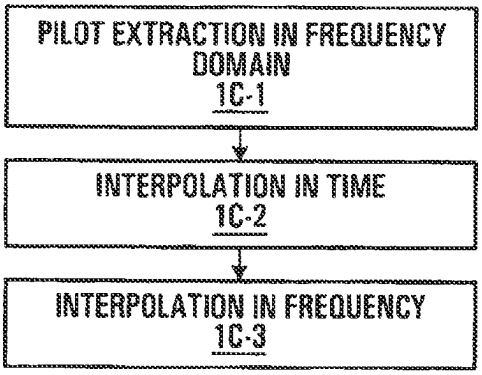


FIG. 1C
(PRIOR ART)

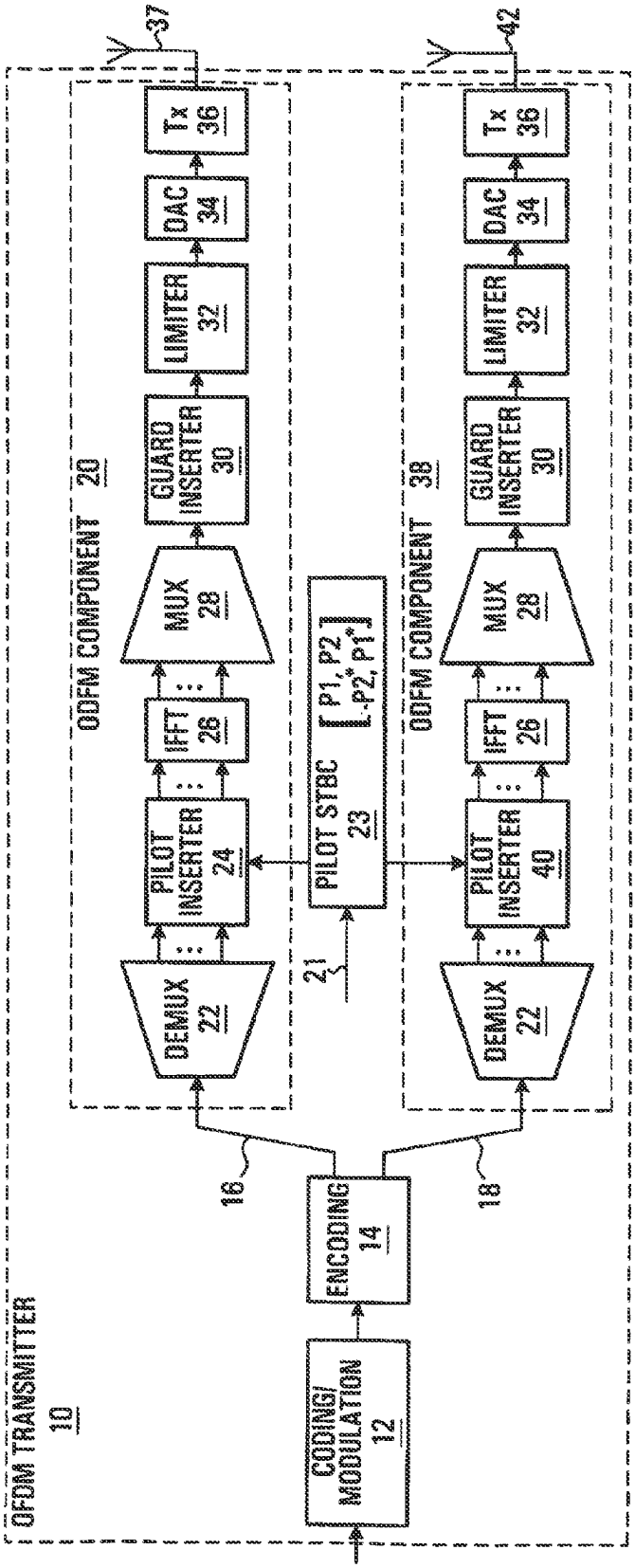

OFDM TRANSMITTER
10
CODING/ MODULATION
12
ENCODING
14
16
18
DEMUX
22
PILOT INSERTER
24
IFFT
26
MUX
28
GUARD INSERTER
30
LIMITER
32
DAC
34
Tx
36
37
ODFM COMPONENT
20
PILOT STBC
23
21
[P1, P2
-P2*, P1*]
ODFM COMPONENT
38
PILOT INSERTER
40
42

FIG. 2

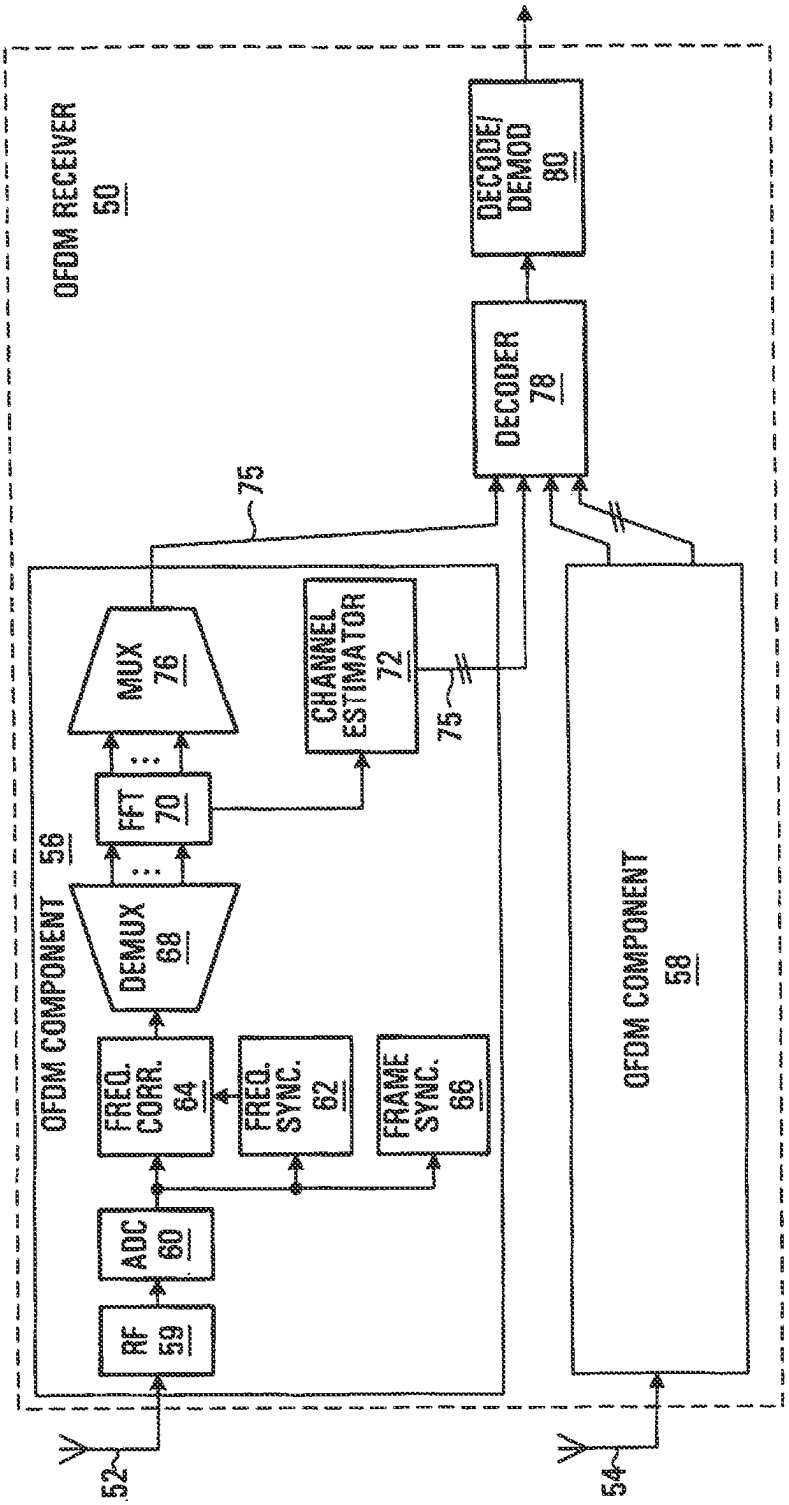

OFDM RECEIVER
50
OFDM COMPONENT
56
RF
59
ADC
60
FREQ. CORR.
64
FREQ. SYNC.
62
FRAME SYNC.
66
DEMUX
68
FFT
70
MUX
76
CHANNEL ESTIMATOR
72
75
75
DECODER
78
DECODE/ DEMOD
80
OFDM COMPONENT
58
52
54

FIG. 3

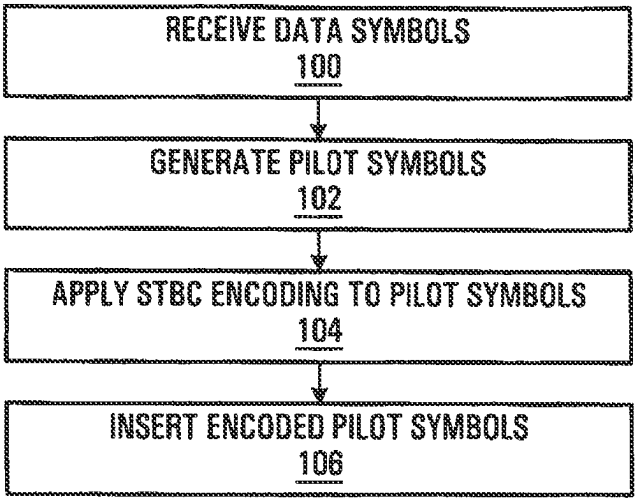

RECEIVE DATA SYMBOLS
100
GENERATE PILOT SYMBOLS
102
APPLY STBC ENCODING TO PILOT SYMBOLS
104
INSERT ENCODED PILOT SYMBOLS
106

FIG. 4

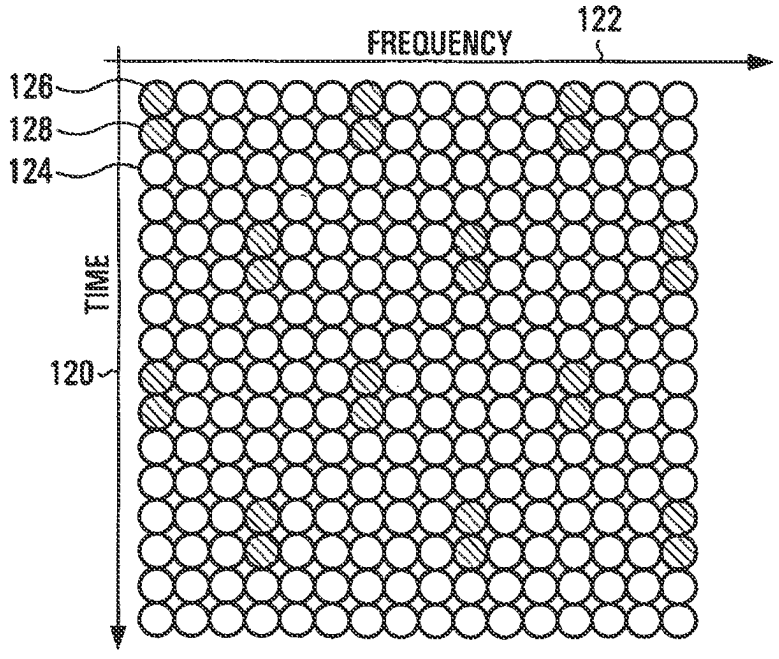

FREQUENCY
122
126
128
124
TIME
120

FIG. 5

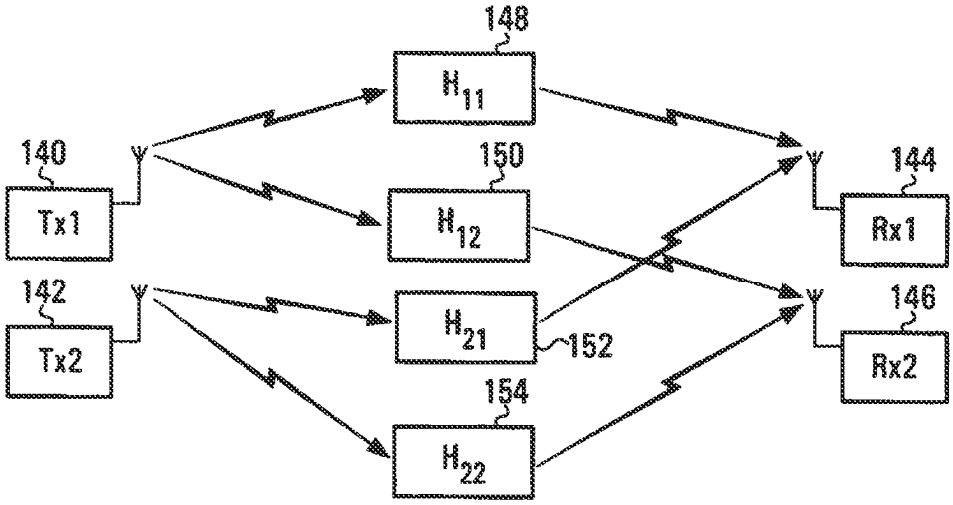


FIG. 6

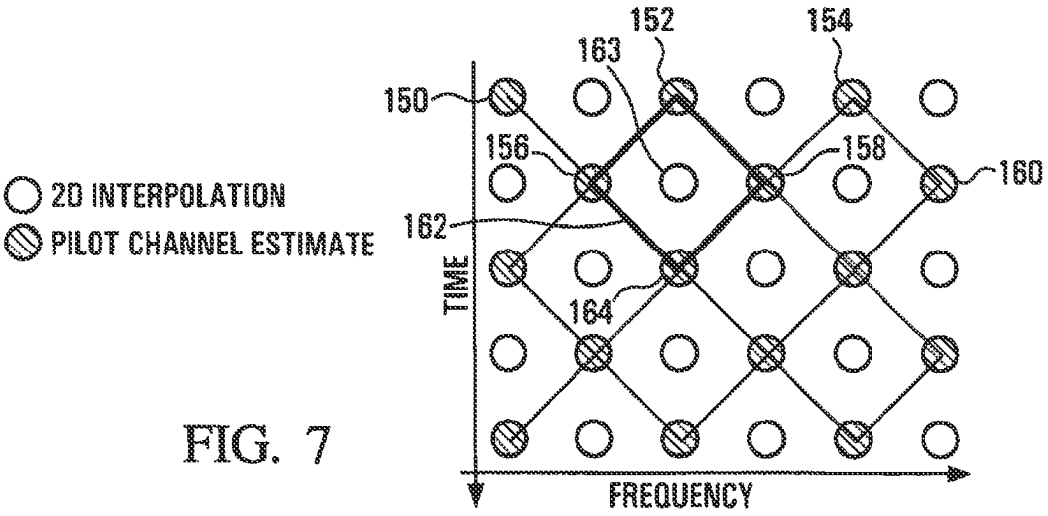


FIG. 7

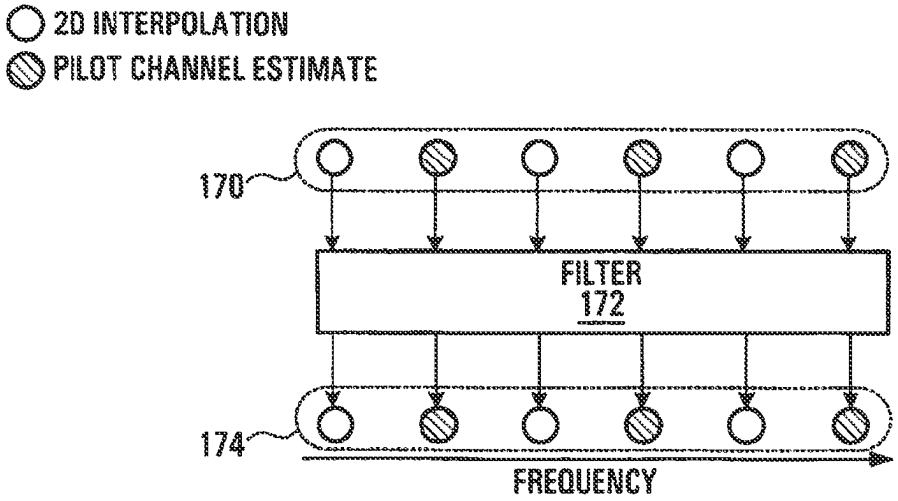


FIG. 8

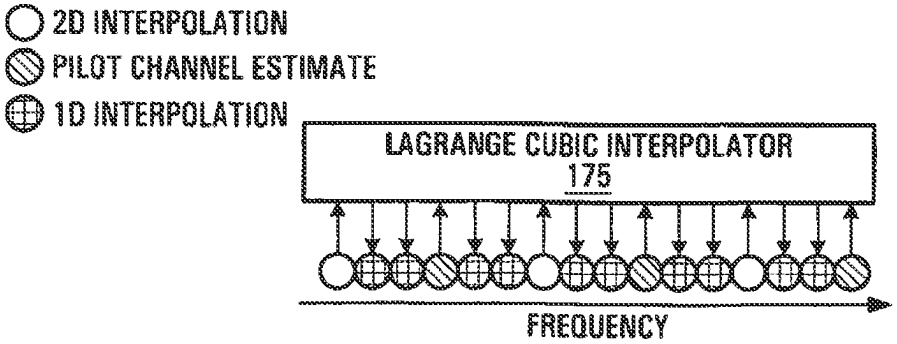


FIG. 9

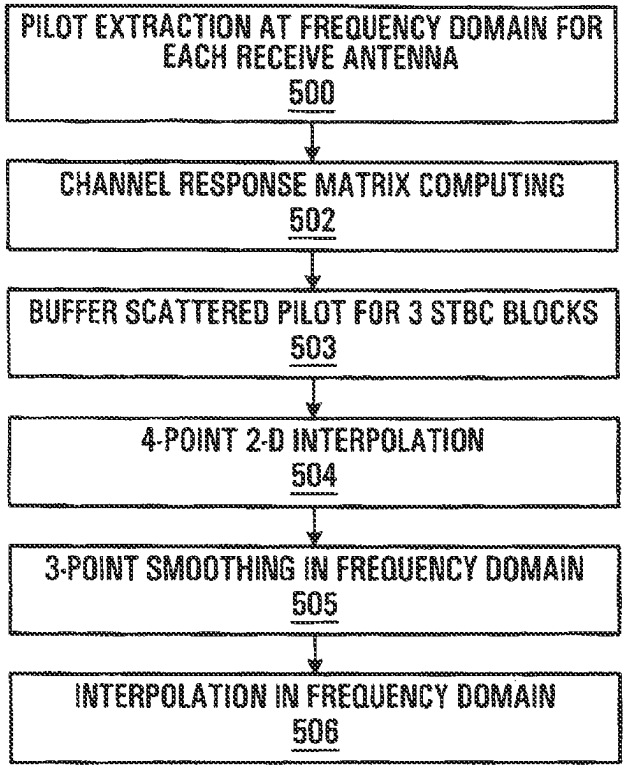

PILOT EXTRACTION AT FREQUENCY DOMAIN FOR EACH RECEIVE ANTENNA
500
CHANNEL RESPONSE MATRIX COMPUTING
502
BUFFER SCATTERED PILOT FOR 3 STBC BLOCKS
503
4-POINT 2-D INTERPOLATION
504
3-POINT SMOOTHING IN FREQUENCY DOMAIN
505
INTERPOLATION IN FREQUENCY DOMAIN
506

FIG. 10

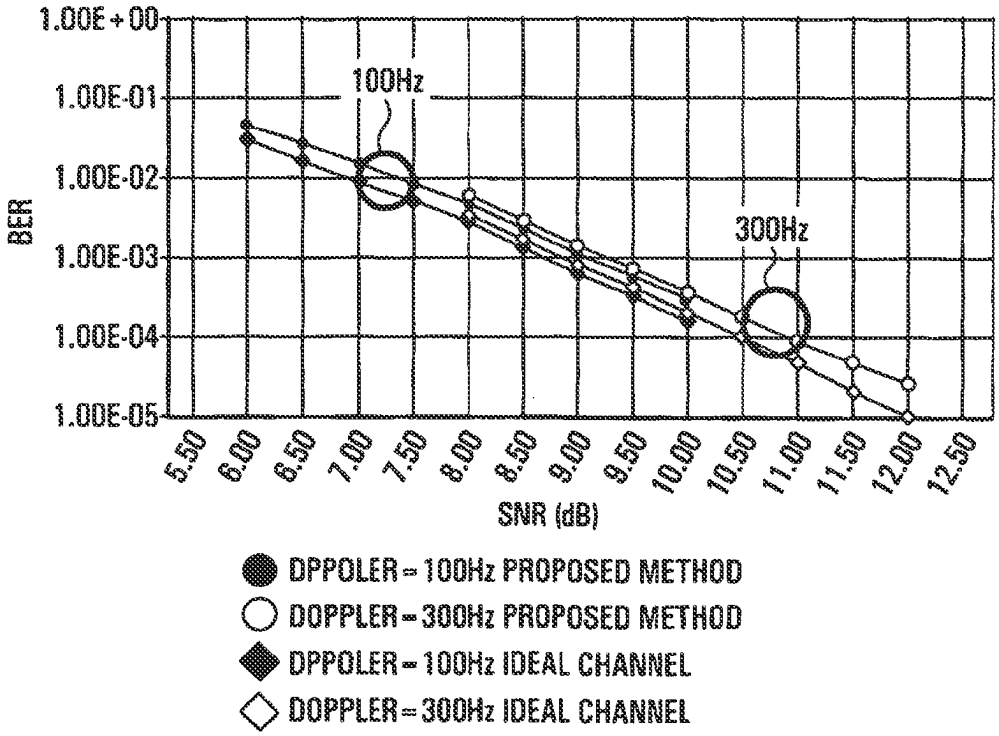

1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
BER
100Hz
300Hz
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
9.50
10.00
10.50
11.00
11.50
12.00
12.50
SNR (dB)
DPPOLER=100Hz PROPOSED METHOD
DOPPLER=300Hz PROPOSED METHOD
DPPOLER=100Hz IDEAL CHANNEL
DOPPLER=300Hz IDEAL CHANNEL

FIG. 11

SCATTERED PILOT PATTERN AND CHANNEL ESTIMATION METHOD FOR MIMO-OFDM SYSTEMS

RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 14/249,127, filed on Apr. 9, 2014, which is itself is a continuation of U.S. application Ser. No. 13/765,523, filed on Feb. 12, 2013, which is itself is a is a continuation of U.S. application Ser. No. 13/586,660, filed on Aug. 15, 2012, and issued as U.S. Pat. No. 8,406,118 on Mar. 26, 2013, which is itself is a continuation of U.S. application Ser. No. 12/468,624, filed on May 19, 2009, and issued as U.S. Pat. No. 8,254,246 on Aug. 28, 2012, which is itself a continuation of U.S. application Ser. No. 11/819,690, filed on Jun. 28, 2007 and issued as U.S. Pat. No. 7,545,734 on Jun. 9, 2009, which is itself a continuation of U.S. application Ser. No. 10/038,883, filed on Jan. 8, 2002, which has issued as U.S. Pat. No. 7,248,559 on Jul. 24, 2007, and claims the benefit thereof, which itself claims the benefit of U.S. Provisional Application No. 60/329,509 filed Oct. 17, 2001, the contents of which are incorporated in its entirety herein by reference.

FIELD OF THE INVENTION

This invention relates to OFDM communication systems, and more particularly to a more efficient use of pilot symbols within such systems.

BACKGROUND OF THE INVENTION

Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is a novel highly spectral efficient technology used to transmit high-speed data through radio channels with fast fading both in frequency and in time.

In wireless communication systems that employ OFDM, a transmitter transmits data to a receiver using many sub-carriers in parallel. The frequencies of the sub-carriers are orthogonal. Transmitting the data in parallel allows the symbols containing the data to be of longer duration, which reduces the effects of multi-path fading. The orthogonality of the frequencies allows the sub-carriers to be tightly spaced, while minimizing inter-carrier interference. At the transmitter, the data is encoded, interleaved, and modulated to form data symbols. Overhead information is added, including pilot symbols, and the symbols (data plus overhead) are organized into OFDM symbols. Each OFDM symbol typically uses 2^n frequencies. Each symbol is allocated to represent a component of a different orthogonal frequency. An inverse Fast Fourier Transform (IFFT) is applied to the OFDM symbol (hence the preference of 2^n frequencies) to generate time samples of a signal. Cyclic extensions are added to the signal, and the signal is passed through a digital-to-analog converter. Finally, the transmitter transmits the signal to the receiver along a channel.

When the receiver receives the signal, the inverse operations are performed. The received signal is passed through an analog-to-digital converter, and timing information is then determined. The cyclic extensions are removed from the signal. The receiver performs an FFT on the received signal to recover the frequency components of the signal, that is, the data symbols. Error correction may be applied to the data symbols to compensate for variations in phase and amplitude caused during propagation of the signal along the channel.

The data symbols are then demodulated, de-interleaved, and decoded, to yield the transmitted data.

In systems employing differential detection, the receiver compares the phase and/or amplitude of each received symbol with an adjacent symbol. The adjacent symbol may be adjacent in the time direction or in the frequency direction. The receiver recovers the transmitted data by measuring the change in phase and/or amplitude between a symbol and the adjacent symbol. If differential detection is used, channel compensation need not be applied to compensate for variations in phase and amplitude caused during propagation of the signal. However, in systems employing coherent detection the receiver must estimate the actual d phase and amplitude of the channel response, and channel compensation must be applied.

The variations in phase and amplitude resulting from propagation along the channel are referred to as the channel response. The channel response is usually frequency and time dependent. If the receiver can determine the channel response, the received signal can be corrected to compensate for the channel degradation. The determination of the channel response is called channel estimation. The inclusion of pilot symbols in each OFDM symbol allows the receiver to carry out channel estimation. The pilot symbols are transmitted with a value known to the receiver. When the receiver receives the OFDM symbol, the receiver compares the received value of the pilot symbols with the known transmitted value of the pilot symbols to estimate the channel response.

The pilot symbols are overhead, and should be as few in number as possible in order to maximize the transmission rate of data symbols. Since the channel response can vary with time and with frequency, the pilot symbols are scattered amongst the data symbols to provide as complete a range as possible of channel response over time and frequency. The set of frequencies and times at which pilot symbols are inserted is referred to as a pilot pattern. The optimal temporal spacing between the pilot symbols is usually dictated by the maximum anticipated Doppler frequency, and the optimal frequency spacing between the pilot symbols is usually dictated by the anticipated delay spread of multi-path fading.

The existing pilot-assisted OFDM channel estimation approaches are designed for conventional one transmitter system. With a scattered pilot arrangement, there are three classes of algorithms:

1-D frequency interpolation or time interpolation
Transformed frequency 1-D interpolation
Independent time and frequency 1-D interpolation

The first class of algorithms is based on the pilot OFDM symbol (all the sub-carriers are used as the pilots) or comb-type of pilots. This approach shown in the flow chart of FIG. **1**A is simple but only suitable for channels with high frequency selectivity or channels with high time fading. The method involves pilot extraction in the frequency domain (step **1**A-**1**) followed by interpolation in time (step **1**A-**2**), or interpolation in frequency (step **1**A-**3**).

The second method shown in the flow chart of FIG. **1**B is aimed for channels with slow Doppler fading and fast frequency fading. It improves the first method by using FFT to reconstruct the channel response back to time domain for noise reduction processing at the expense of FFT/IFFT computing for the channel estimation separately. The method begins with pilot extraction in the frequency domain (step **1**B-**1**), which may be followed by interpolation in frequency (step **1**B-**2**). Then an inverse fast Fourier transform (step **1**B-**3**), smoothing/de-noise processing (step **1**B-**4**), and finally a fast Fourier transform (**1**B-**5**) steps are executed.

The third method shown in the flow chart of FIG. **1**C can be used to estimate channel for mobile applications, where both fast time fading and frequency fading exist. However it needs a relatively high density of pilots and a completed interpolator. This method involves pilot extraction in the frequency domain (step **1**C-**1**) this is followed by interpolation in time (step **1**C-**2**) and interpolation in frequency (step **1**C-**3**).

In the propagation environment with both high frequency dispersion and temporal fading, the channel estimation performance can be improved by the increase of pilot symbol density at the price of the reduction of the spectral efficiency of the data transmission. To interpolate and reconstruct the channel response function from the limited pilots to achieve reliable channel estimation with the minimum overhead is a challenging task.

There are a variety of existing standard pilot patterns. In environments in which the channel varies only slowly with time and frequency, the pilot symbols may be inserted cyclically, being inserted at an adjacent frequency after each time interval. In environments in which the channel is highly frequency dependent, the pilot symbols may be inserted periodically at all frequencies simultaneously. However, such a pilot pattern is only suitable for channels that vary very slowly with time. In environments in which the channel is highly time dependent, the pilot symbols may be inserted continuously at only specific frequencies in a comb arrangement to provide a constant measurement of the channel response. However, such a pilot pattern is only suitable for channels that vary slowly with frequency. In environments in which the channel is both highly frequency and highly time dependent (for example, mobile systems with much multi-path fading), the pilot symbols may be inserted periodically in time and in frequency so that the pilot symbols form a rectangular lattice when the symbols are depicted in a time-frequency diagram.

In OFDM communication systems employing coherent modulation and demodulation, the receiver must estimate the channel response at the frequencies of all sub-carriers and at all times. Although this requires more processing than in systems that employs differential modulation and demodulation, a significant gain in signal-to-noise ratio can be achieved using coherent modulation and demodulation. The receiver determines the channel response at the times and frequencies at which pilot symbols are inserted into the OFDM symbol, and performs interpolations to estimate the channel response at the times and frequencies at which the data symbols are located within the OFDM symbol. Placing pilot symbols more closely together (in frequency if a comb pattern is used, in time if a periodic pattern is used, or in both frequency and in time if a rectangular lattice pattern is used) within a pilot pattern results in a more accurate interpolation. However, because pilot symbols are overhead, a tighter pilot pattern is at the expense of the transmitted data rate.

Existing pilot patterns and interpolation techniques are usually sufficient if the channel varies slowly with time (for example for nomadic applications). However, if the channel varies quickly with time (for example, for mobile applications), the time interval between pilot symbols must be reduced in order to allow an accurate estimation of the channel response through interpolation. This increases the overhead in the signal.

The problem of minimizing the number of pilot symbols while maximizing the accuracy of the interpolation is also particularly cumbersome in Multiple-Input Multiple-Output (MIMO) OFDM systems. In MIMO OFDM systems, the transmitter transmits data through more than one transmitting antenna and the receiver receives data through more than one receiving antenna. The binary data is usually divided between the transmitting antennae, although the same data may be transmitted through each transmitting antenna if spatial diversity is desired. Each receiving antenna receives data from all the transmitting antennae, so if there are M transmitting antennae and N receiving antennae, then the signal will propagate over M×N channels, each of which has its own channel response. Each transmitting antenna inserts pilot symbols into the same sub-carrier location of the OFDM symbol which it is transmitting. In order to minimize interference at the receiver between the pilot symbols of each transmitting antenna, each transmitting antenna typically blinks its pilot pattern on and off. This increases the temporal separation of the pilot symbols for each transmitter, reducing the accuracy of the interpolation used to estimate the channel response. In MIMO-OFDM systems a simple and fast channel estimation method is particularly crucial because of the limitation of the computational power for estimating M×N channels, while in SISO-OFDM system only one channel needs to be estimated.

SUMMARY OF THE INVENTION

Channel estimation methods are provided which are based on the partial interpolation of a scattered pilot by using true 2-D interpolation; and additionally, simple 1-D interpolation is used reconstruct the entire channels. This method has a reduced scattered pilot overhead, and is at least an order of magnitude less computationally complex than some existing methods. In general, the proposed method of channel estimation is more robust in channels with high Doppler spread, and provides better performance than some existing methods and requires the less buffering of the OFDM symbols for the coherent detection at the receiver than in some methods.

The methods allow fewer pilot symbols to be placed within each OFDM symbol, while still allowing accurate interpolation of the channel response. The data rate of an MIMO-OFDM system is thereby improved.

According to a first aspect of the invention, there is provided a method of inserting pilot symbols into Orthogonal Frequency Division Multiplexing (OFDM) frames transmitted on a plurality N of transmitting antenna, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols, the method comprising the steps of: for the N transmit antennas, transmitting sets of N pilot symbols, each set being in a location within a scattered pattern in time-frequency, each set of N pilot symbols comprising a pilot symbol for each antenna.

In some embodiments, transmitting sets of N pilot symbols, each set being in a location within a scattered pattern in time-frequency comprises: transmitting a set of N pilot symbols in a respective location within the scattered pattern on a same sub-carrier.

In some embodiments, for the N transmit antennas, transmitting sets of N pilot symbols, each set being in a location within a scattered pattern in time-frequency comprises: inserting sets of N pilot symbols at locations that form at least one diagonal arrangement in time-frequency.

In some embodiments, inserting sets of N pilot symbols comprises: when N is equal to two, for each antenna, alternating insertion of null symbol locations and pilot symbols in the at least one diagonal arrangement for a first antenna of the pair of antennas and alternating insertion of pilot symbols and null symbol locations in the at least one diagonal arrangement for a second antenna of the pair of antennas, wherein the null

symbol locations of the first antenna correspond to a same location in time-frequency as the pilot symbols of the second antenna, and vice versa.

In some embodiments, the method further comprises for each location within a scattered pattern in time-frequency: generating a group of L uncoded pilot symbols; performing space time block coding (STBC) on the group of L uncoded pilot symbols to produce an N×N STBC block, L and N determining an STBC code rate; transmitting one row or column of the STBC block on each antenna on a specific sub-carrier.

In some embodiments, the method further comprises transmitting the sets of N pilot symbols with a power level greater than a power level of data symbols, depending upon a value reflective of channel conditions.

In some embodiments, the method further comprises transmitting the sets of N pilot symbols with a power level which is dynamically adjusted to ensure sufficiently accurate reception as a function of a modulation type applied to sub-carriers carrying data.

In some embodiments, transmitting sets of N pilot symbols, each set being in a location within a scattered pattern in time-frequency comprises: providing a first plurality of equally spaced sub-carrier positions; providing a second plurality of equally spaced sub-carrier positions offset from said first plurality; inserting the sets of N pilot symbols alternately in time using the first plurality of equally spaced sub-carrier positions and the second plurality of equally spaced sub-carrier positions.

In some embodiments, the second plurality of equally spaced sub-carrier positions is offset from the first plurality of equally spaced-subcarrier positions by half the spacing between adjacent sub-carriers of the first plurality of sub-carrier positions thereby forming a diamond shaped arrangement.

In some embodiments, the method further comprises inserting sets of N pilot symbols in an OFDM resource for an additional group of N transmitting antennas wherein transmitting sets of N pilot symbols in a respective pattern in time-frequency for the additional group of N transmitting antennas comprises: employing the same respective pattern of pilot symbols as the N transmitting antennas where N≥2, but offset in at least one of time and frequency.

According to a second aspect of the invention, there is provided a method comprising: providing a first transmitter implementing the method according to the first aspect of the invention; providing at least one other transmitter implementing the method according to the first aspect of the invention using scattered patterns offset from those used by the first transmitter.

According to a third aspect of the invention, there is provided a transmitter comprising: a plurality N of transmit antennas; an OFDM frame generator that inserts pilot symbols into Orthogonal Frequency Division Multiplexing (OFDM) frames transmitted on the plurality N of transmit antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols, such that for the N transmit antennas, sets of N pilot symbols are transmitted, each set being in a location within a scattered pattern in time-frequency, each set of N pilot symbols comprising a pilot symbol for each antenna.

In some embodiments, a set of N pilot symbols in a respective location within the scattered pattern is transmitted on a same sub-carrier.

In some embodiments, the transmitter is further operable to, for each location in the scattered pattern: generate a group of L uncoded pilot symbols; perform space time block coding (STBC) on the group of L pilot symbols to produce an N×N STBC block; transmit one row or column of the STBC block on each antenna.

In some embodiments, the transmitter is further operable to transmit the sets of N pilot symbols with a power level greater than a power level of data symbols depending on a value reflective of channel conditions.

In some embodiments, the transmitter is further operable to transmit the sets of N pilot symbols with a power level which is dynamically adjusted to ensure sufficiently accurate reception.

In some embodiments, the OFDM frame generator is operable to: define a first plurality of equally spaced sub-carrier locations; define a second plurality of equally spaced sub-carrier locations offset from said first plurality; wherein the sets of N pilot symbols are inserted alternately in time using the first plurality of equally spaced sub-carrier locations and the second plurality of equally spaced sub-carrier locations.

In some embodiments, spacing between locations of the scattered pattern in time-frequency is optimized to allow a fast extraction of scattered pilot symbols without requiring the computation of a complete FFT.

According to a fourth aspect of the invention, there is provided a receiver comprising: a plurality N of receive antennas for receiving OFDM symbols comprising: sets of N pilot symbols transmitted from N antennas in a scattered pattern in time-frequency, the sets of N pilot symbols for each respective pattern in time-frequency inserted such that sets of N pilot symbols from different antennas do not occupy a same location in time-frequency; and data symbols in time-frequency; and a channel estimator for comparing the received sets of N pilot symbols with pilot symbol values known to be transmitted by a transmitter.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail with reference to the accompanying Figures, in which:

FIG. **1**A illustrates a flow-chart of an example for three examples of conventional OFDM Channel Estimation;

FIG. **1**B illustrates a flow-chart of another example of conventional OFDM Channel Estimation;

FIG. **1**C illustrates a flow-chart of another example of conventional OFDM Channel Estimation;

FIG. **2** is a block diagram of a Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (OFDM) transmitter provided by an embodiment of the invention;

FIG. **3** is a block diagram of an OFDM receiver;

FIG. **4** is a flowchart of a method by which an OFDM transmitter inserts pilot symbols into an OFDM frame according to one embodiment of the invention;

FIG. **5** is a diagram of a pilot pattern generated using the method of FIG. **4**;

FIG. **6** is a block diagram of a MIMO system showing the channel transfer functions between two transmit antennas and two receive antennas;

FIG. **7** is a time frequency diagram showing channel estimate positions for pilot channel estimation;

FIG. **8** schematically illustrates a step of filtering estimated and interpolated pilot channel estimates;

FIG. **9** shows schematically the step of interpolating between the channel estimates previously determined to provide channel estimates for all sub-carriers and all times;

FIG. **10** is a flow chart summarizing the overall channel estimation method provided by an embodiment of the invention; and

FIG. **11** is an example of a set of performance results obtained using the method of FIG. **10**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following sections describe a MIMO-OFDM transmitter/receiver and scattered pilot insertion. By way of introduction, a OFDM frame consists of the preamble OFDM symbols and regular OFDM symbols. Each OFDM symbol uses a set of orthogonal sub-carriers. When there are two transmit antennas, two OFDM symbols form a STTD block. For regular OFDM symbols, some sub-carriers are used as pilot sub-carriers to carry pilot symbols while the others are used as data sub-carriers to carry data symbols. The pilot sub-carriers are modulated by pilot symbols generated by QPSK. The data sub-carriers are modulated by complex data symbols generated by QAM mapping. STTD coding is applied to the pilot sub-carrier pairs located at the same frequency within one STTD block.

Referring to FIG. **2**, a block diagram of a Multiple-Input Multiple-Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) transmitter provided by an embodiment of the invention is shown. The OFDM transmitter shown in FIG. **2** is a two-output OFDM transmitter, though more generally there may be a plurality of M transmitting antennae. An OFDM transmitter **10** takes binary data as input but data in other forms may be accommodated. The binary data is passed to a coding/modulation primitive **12** responsible for encoding, interleaving, and modulating the binary data to generate data symbols, as is well known to those skilled in the art. The coding/modulation primitive **12** may include a number of processing blocks, not shown in FIG. **2**. An encoder **14** applies Space-Time Block Coding (SBTC) to the data symbols. The encoder **14** also separates the data symbols into a first processing path **16** and a second processing path **18**, by sending alternate data symbols along each of the two processing paths. In the more general case in which the OFDM transmitter **10** includes M transmitting antennae, the encoder **14** separates the data symbols into M processing paths.

The data symbols sent along the first processing path **16** are sent to a first OFDM component **20**. The data symbols are first passed to a demultiplexer **22** in the first OFDM component **20**, after which the data symbols are treated as sub-carrier components. The data symbols are then sent to a pilot inserter **24**, where pilot symbols are inserted among the data symbols. Collectively, the data symbols and pilot symbols are referred to hereinafter simply as symbols. The symbols are passed to an Inverse Fast Fourier Transform (IFFT) processor **26**, then to a multiplexer **28** where they are recombined into a serial stream. A guard inserter **30** adds prefixes to the symbols. Finally, the OFDM signals are passed through a hard limiter **32**, a digital-to-analog converter **34**, and a radio frequency (RF) transmitter **36** which transmits OFDM symbols as a signal through a first transmitting antenna **37**. In most embodiments, each element in the first OFDM component **20** is a processor, a component of a larger processor, or a collection of processors or any suitable combination of hardware, firmware and software. These might include general purpose processors, ASICs, FPGAs, DSPs to name a few examples.

The pilot inserter **24** is connected to receive space-time coded pilot symbols from pilot STBC function **23** which performs STBC on pilot symbols **21**. The pilot STBC block **23** takes two pilot symbols at a time for example P_1 and P_2 as indicated in FIG. **2** and generates an STBC block consisting of a two by two matrix having (P_1, P_2) in the first row and having ($-P_2^*$, P_1^*) in the second row. It is the first row of this STBC block that is inserted by the pilot inserter **24**.

The data symbols sent along the second processing path **18** are sent to a second OFDM component **38** which includes processors similar to those included in the first OFDM component **20**. However, the pilot inserter **40** inserts encoded pilot symbols from the second row of the STBC block produced by the pilot STBC function **23**. The symbols sent along the second processing path **18** are ultimately transmitted as a signal through a second transmitting antenna **42**.

Referring now to FIG. **3**, a block diagram of an MIMO-OFDM receiver is shown. An OFDM receiver **50** includes a first receiving antenna **52** and a second receiving antenna **54** (although more generally there will be one or more receiving antennae). The first receiving antenna **52** receives a first received signal. The first received signal is a combination of the two signals transmitted by the two transmitting antennae **37** and **42** of FIG. **2**, although each of the two signals will have been altered by a respective channel between the respective transmitting antenna and the first receiving antenna **52**. The second receiving antenna **54** receives a second received signal. The second received signal is a combination of the two signals transmitted by the two transmitting antennae **37** and **42** of FIG. **2**, although each of the two signals will have been altered by a respective channel between the respective transmitting antenna and the second receiving antenna **54**. The four channels (between each of the two transmitting antennae and each of the two receiving antennae) may vary with time and with frequency, and will usually be different from each other.

The OFDM receiver **50** includes a first OFDM component **56** and a second OFDM component **58** (although in general there will be N OFDM components, one for each receiving antenna). The first OFDM component **56** includes a RF receiver **59**, and an analog-to-digital converter **60**, which converts the first received signal into digital signal samples. The signal samples are passed to a frequency synchronizer **62** and a frequency offset corrector **64**. The signal samples are also fed to a frame/time synchronizer **66**. Collectively, these three components produce synchronized signal samples.

The synchronized signal samples represent a time sequence of data. The synchronized signal samples are passed to a demultiplexer **68**, then passed in parallel to a Fast Fourier Transform (FFT) processor **70**. The FFT processor **70** performs an FFT on the signal samples to generate estimated received symbols which are multiplexed in MUX **76** and sent as received symbols to decoder **78**. Ideally, the received symbols would be the same as the symbols fed into the IFFT processor **26** at the OFDM transmitter **10**. However, as the received signals will have likely been altered by the various propagation channels, the first OFDM component **56** must correct the received symbols by taking into account the channels. The received symbols are passed to a channel estimator **72**, which analyses received pilot symbols located at known times and frequencies within the OFDM frame. The channel estimator **72** compares the received pilot symbols with what the channel estimator **72** knows to be the values of the pilot symbols as transmitted by the OFDM transmitter **10**, and generates an estimated channel response for each frequency

and time within the OFDM symbol. The estimated channel responses are passed to decoder **78**. The channel estimator **72** is described in detail below.

The second OFDM component **58** includes similar components as are included in the first OFDM component **56**, and processes the second received signal in the same manner as the first OFDM component **56** processes the first received signal. Each OFDM component passes OFDM symbols to the decoder **78**.

The decoder **78** applies STBC decoding to the OFDM symbols, and passes the symbols to a decoding/demodulating primitive **80** responsible for decoding, de-interleaving, and demodulating the symbols to generate output binary data, as is well known to those skilled in the art. The decoding/demodulation primitive **80** which may include a number of additional processing blocks, not shown in FIG. **2**. Each element in the OFDM components **56** and **58** is a processor, a component of a larger processor, or a collection of processors.

Referring now to FIG. **4**, a method by which each of the pilot inserters **24** and **40** of FIG. **2** inserts pilot symbols among the data symbols is shown. The method will be described with reference to the pilot inserter **24** in the first OFDM component **20**. At step **100**, the pilot inserter **24** receives data symbols from the demultiplexer **22**. At step **102** the pilot STBC function **23** generates (or receives) two pilot symbols. At step **104** the pilot STBC function **23** applies STBC encoding to the pilot symbols, so as to generate an STBC block of encoded pilot symbols. The encoded pilot symbols generated for the first transmitting antenna **37** will be one row of the STBC block and will have a number equal to the number of transmitting antennae in the OFDM transmitter. Thus, for a two antenna system a 2×2 STBC block is generated.

At step **106** the pilot inserter **24** inserts the encoded pilot symbols within the OFDM symbol. Encoded pilot symbols are inserted in a diamond lattice pattern. The diamond lattice pattern uses the same frequencies as the other diamond lattice patterns, but has a temporal offset from the other diamond lattice patterns. Preferably, the temporal offset for each diamond lattice pattern is one symbol (in the time direction) from another diamond lattice pattern, so that the diamond lattice patterns use consecutive symbols in the time direction of the OFDM frame.

The diamond lattice pattern in which each encoded pilot symbol is inserted within the OFDM frame is preferably a perfect diamond lattice pattern. To achieve this, the encoded pilot symbol is inserted at each of a first subset of frequencies. The frequencies within the first subset of frequencies are spaced equally apart by a pilot spacing. The encoded pilot symbol is inserted at each of the first subset of frequencies for an STBC block (two OFDM symbols). At some later time, the encoded pilot symbols are inserted at each of a second subset of frequencies. The frequencies within the second subset of frequencies are shifted from the frequencies within the first subset of frequencies by half of the pilot spacing within the frequency direction. The pilot inserter **24** continues to insert encoded pilot symbols, alternating between the first subset of frequencies and the second subset of frequencies.

Alternatively, a different pilot pattern can be used, as long as the same pilot pattern is used for each of the at least one encoded pilot symbols unique to the transmitting antenna **37**, and as long as the pilot patterns for the encoded pilot symbols are offset from each other in the time direction of the OFDM frame. For example, a regular diagonal lattice pattern may be used, the diamond shaped lattice being a special case of this.

The pilot inserter **40** inserts pilot symbols using the same method, although the pilot symbols will be the other half of the STBC block **42**. The encoded pilot symbols unique to the second transmitting antenna **42** are inserted in the OFDM frame at the same symbol locations at which the encoded pilot symbols corresponding to the first transmitting antenna **37** are inserted.

Referring to FIG. **5**, an example pilot pattern generated using the method of FIG. **4** is shown. Pilot and data symbols are spread over the OFDM frame in a time direction **120** and a frequency direction **122**. Most symbols within the OFDM frame are data symbols **124**. A first set of encoded pilot symbols **126** corresponding to the first transmitting antenna **37** is inserted in a diamond lattice pattern. A second set of encoded pilot symbols **128** corresponding to the first transmitting antenna **37** is inserted in a diamond lattice structure at the same frequencies as the first set of encoded pilot symbols, but offset by one OFDM symbol location in the time direction **120**. In the illustrated example two of every four OFDM symbols carry encoded pilot symbols. Each other transmitting antenna transmits using the same pattern. The pairs of consecutive pilot symbols on a sub-carrier consist of two raw pilot symbols STBC encoded. The same pattern is transmitted by the second antenna.

The power of the encoded pilot symbols **126**, **128** may be increased compared to the traffic data symbol **124**. The power increase of the encoded pilot can be dynamically adjusted with respect to the transmitting data symbol power level or modulation type (QAM size), or as a function of channel quality. The location of diamond lattice pattern may also be optimized to allow a fast extraction of scattered pilot without using the computing. This may be achieved if the pilot sub-carriers are spaced in the frequency direction by 2^n. In the multiple base station transmission arrangement, the location of the diamond lattice pattern can be cyclic offset both in time direction and in frequency direction amongst adjacent base stations to form a diamond lattice re-use pattern.

Referring now to FIGS. **6** to **10**, a channel estimation method is described which is based on the pilot insertion method above. This invention presents a simple 2-dimensional channel interpolator for MIMO-OFDM system with low pilot density for fast fading channels both in time and in frequency. The goal of channel estimation is to estimate the channel characteristics for each sub-carrier and at each time for each possible transmit antenna, receive antenna combination. Referring to FIG. **13**, for the two transmit antenna, two receive antenna example, shown are two transmit antennas Tx1 **140** and Tx2 **142** and two receive antennas Rx1 **144** and Rx2 **146**. Channel estimation estimates a channel for each sub-carrier and at each time between Tx1 **140** and Rx1 **144** indicated as each H_{11} **148**, a channel between Tx1 **140** and Rx2 **146** indicated by transfer function H_{12} **150**, a channel estimate for transmitter Tx2 **142** to Rx1 **144** indicated as transfer function H_{22} **152** and finally, a channel estimate for transmitter Tx2 **142** to receiver Rx2 **146** indicated as transfer function H_{21} **154**.

Some advantages for the proposed method compared to some existing methods are: (1) robust to high mobility-speed (2) a reduction of the scattered pilot grid density and therefore a reduction of the pilot overhead.

Let P_1 and P_2 be the two pilot symbols encoded in an STBC block and transmitted by two antennas on one sub-carrier in consecutive OFDM symbols. Then at the first receive antenna, the following relationship exists for each sub-carrier on which pilot symbols are transmitted, where it is assumed the channel response H_{ij} is constant over two OFDM frames:

$$\begin{bmatrix} Y_{1,1} \\ Y_{1,2} \end{bmatrix} = \begin{bmatrix} P_1 & P_2 \\ -P_2^* & P_1^* \end{bmatrix} \begin{bmatrix} H_{11} \\ H_{21} \end{bmatrix}$$

$Y_{1,1}$ is the received data on the first antenna on the sub-carrier in the first of the two consecutive OFDM symbols, and $Y_{1,2}$ is the received data on the first antenna on the sub-carrier in the second of the two consecutive symbols. This can be solved for H_{11}, H_{21} to yield:

$$\begin{bmatrix} H_{11} \\ H_{21} \end{bmatrix} = \frac{1}{|P_1|^2 + |P_2|^2} \begin{bmatrix} P_1^* & -P_2 \\ P_2^* & P_1 \end{bmatrix} \begin{bmatrix} Y_{1,1} \\ Y_{1,2} \end{bmatrix}$$

A similar process for the second antenna yields

$$\begin{bmatrix} H_{12} \\ H_{22} \end{bmatrix} = \frac{1}{|P_1|^2 + |P_2|^2} \begin{bmatrix} P_1^* & -P_2 \\ P_2^* & P_1 \end{bmatrix} \begin{bmatrix} Y_{2,1} \\ Y_{2,2} \end{bmatrix}$$

where $Y_{2,1}$ is the received data on the second antenna on the sub-carrier in the first of the two consecutive OFDM symbols, and $Y_{2,2}$ is the received data on the second antenna on the sub-carrier in the second of the two consecutive OFDM symbols.

Using this techniques, a channel estimate is made for each pilot sub-carrier, and for each pair of OFDM symbols used to transmit STBC blocks.

For the example of FIG. **12**, the result is a channel estimate, for each of the possible channels (these are for channels in this example as shown in FIG. **13**) for each pair of pilot symbols transmitted. This is illustrated in FIG. **14** where only sub-carriers used to transmit pilots are shown. A channel estimate **150** is generated for each pair of (consecutive in time) OFDM frames for each pilot sub-carrier. This results in channel estimates **150**, **152**, **154** for the first and second frames, and channel estimates **156**, **158**, **160** for the fifth and sixth frames and so on.

The channel estimates are made on a STBC block by block basis so that the pattern of channel estimate shown in FIG. **7** develops over time. The next step in the process is to perform an interpolation based on the channel estimate of FIG. **7** to obtain channel estimates for the places in FIG. **7** which do not represent pilot channel positions. The manner in which this is done will be described for a single example, namely the unknown channel estimate indicated at **163** of FIG. **7**. Channel estimates are buffered on an ongoing basis and when the four channel estimates **152**, **156**, **158** and **164** forming a diamond **162** surrounding the unknown channel estimate **163** have been computed, it is time to interpolate to obtain a channel estimate for the unknown point **163**. The channel transfer function at the sub-carrier located at the centre of the diamond can be obtained from a simple 4 points two-dimensional interpolator. Three points two-dimensional interpolators can be used to obtain the channel estimates corresponding to the first or last useful sub-carrier:

$$H_{new}(n+1, k) = \frac{1}{4}(H(n, k) + H(n+2, k) + H(n+1, k-1) + H(n+1, k+1))$$

$$\text{where } (k = 2, \ldots, N_{pilot} - 1)$$

-continued

$$H_{new}(n+1, 1) = \frac{1}{4}(H(n, 1) + H(n+2, 1) + 2H(n+1, 2))$$

$$H_{new}(n+1, N_{pilot}) = \frac{1}{4}(H(n, N_{pilot}) + H(n+2, N_{pilot}) + 2H(n, N_{pilot} - 1))$$

where k is the pilot sub-carrier index, n is the channel estimate index (or STBC block number—one channel estimate per sub-carrier for every two symbols), and N_{pilot} is the number of pilot sub-carriers (**6** in the example of FIG. **7**). H_{new} is the newly interpolated channel estimate for the i^{th} channel estimation period, and the j^{th} pilot sub-carrier. H(i, j) is the channel estimate determined as described previously from the pilot symbols. A three points interpolator would also be performed for the last STBC blocks in the OFDM frame (i.e. the last two OFDM symbols).

These calculations are done for each transmit antenna, receiver antenna combination. It is noted that this is just one example of how the channel estimates can be interpolated.

If the original distance between pilot sub-carriers in the frequency direction is D_f, after first step of interpolation described above, the pilot sub-carriers' separation becomes

$$\frac{D_f}{2}.$$

In some embodiments, to remove noise, the channel estimates thus computed are filtered at each channel estimation period. This is shown in FIG. **6** where the channel estimates **170** for one channel estimation period are shown entering filter **172** to produce filtered channel estimates. For example, a simple 3 point moving iterative smoothing algorithm may be applied to H':

$$H'_{sm}(n, k) = H'_{sm}(n, k-1) + \frac{1}{3}(H'(n, k+1) + H'_{sm}(n, k-2))$$

where k=3, . . . , 2 N_{pilot}−2. It is to be understood that other filtering algorithms may be employed.

After the interpolation of the pilot channel estimate as summarized in FIG. **7**, there will be a channel estimate for each sub-carrier on which pilot channel information was transmitted and for each two OFDM symbol period over which pilot channeling information was transmitted. Referring to FIG. **5**, this means that there will be a channel estimate for each antenna for time frequency points which are shaded to indicate that pilot channel information was transmitted. There will also be channel estimates for the time frequency point in the centre of the diamond shaped lattice structure of FIG. **7**. However, for points which are not pilot symbol transmission time-frequency points nor points which are at the centre of a diamond shaped lattice of such points, there will be no channel estimate yet computed. The next step is to perform a further interpolation step to develop channel estimates for these other points.

In some embodiments, Cubic Lagrange interpolation and linear interpolation (for the sub-carriers near the first and the last useful sub-carrier) in the frequency direction are used to obtain the channel transfer function at all sub-carriers for each STBC block (for each pair of OFDM symbols).

The coefficients of the Cubic Lagrange interpolator can be calculated as

$$\mu(i) = \frac{i}{D_f/2} \qquad i = 1, 2, \ldots, \frac{D_f}{2}$$

$$q_{-1}(\mu) = -\frac{1}{6}\mu^3 + \frac{1}{2}\mu^2 - \frac{1}{3}\mu$$

$$q_0(\mu) = \frac{1}{2}\mu^3 - \mu^2 - \frac{1}{2}\mu + 1$$

$$q_1(\mu) = -\frac{1}{2}\mu^3 + \frac{1}{2}\mu^2 + \mu$$

$$q_2(\mu) = -\frac{1}{6}\mu^3 - \frac{1}{6}\mu$$

The channel transfer functions at data sub-carriers are given by

$$H_{interp}\left((j-1)\cdot\frac{D_f}{2} + i\right) = \sum_{n=-1}^{2} q_n(\mu(i)) \cdot H'_{sm}(j+n)$$

where j=2, . . . , N_{pilot}−2.

This is illustrated in FIG. **9** where the estimated channel responses are fed to the Legrange cubic interpolator function **175** which outputs values for all intermediate sub-carriers. Other interpolations may alternatively be employed.

In some embodiments, every OFDM symbol contains some pilot insertion points and as such this completes the interpolation process. In other embodiments, there are some OFDM symbols which do not have any pilot insertion points. To get channel estimates for these OFDM symbols, an interpolation in time of the previously computed channel estimates is performed. In high mobility applications, pilots should be included in every OFDM symbol avoiding the need for this last interpolation in time step.

FIG. **10** presents an overall block diagram of the interpolation method proposed for two transmit antennas. An example set of performance results for the proposed MIMO-OFDM channel estimation algorithm is shown in FIG. **10**. The performance of the 2-D channel estimation algorithm is close to the performance of ideal channel (only 0.5 dB loss) at very high Doppler spread.

Referring now to FIGS. **10** and **3**, the channel estimation method is carried out by the channel estimator **72** in order to estimate a channel response for each sub-carrier and each OFDM symbol within an OFDM frame. The channel estimation method starts at step **500** by extracting the pilot symbols in the frequency domain for each receive antenna. This is followed by a channel response matrix computing step **502**; whereby the received signal received by the receiving antenna is decoded, which in effect performs a time average of the encoded pilot symbols at each point in the pilot pattern. For example, suppose the receiving antenna receives an OFDM frame having a pilot pattern as shown in FIG. **5** (although the symbol **126** will now be a linear combination of the encoded pilot symbol transmitted at this location by each of the transmitting antenna, and the symbol **128** will be a linear combination of the encoded pilot symbol transmitted at this location by each of the transmitting antenna). Following decoding, the pilot symbol at symbol location **126** will be an average of the pilot symbol received at symbol location **126** and the pilot symbol received at symbol location **128**. The time averaging effect produced by the STBC decoding, during step **503**, can be viewed as a pre-processing step, as can steps **500** and **502**.

The actual channel estimation method can be described broadly in four steps. Following step **503**, during step **504** the channel estimator **72** estimates the channel response for each of a plurality of pilot symbols. For a diamond lattice pattern, the plurality of pilot symbols will be four pilot symbols forming a single diamond pattern. The channel estimator **72** estimates the channel response of a central symbol, the central symbol having a time direction value and a frequency direction value bounded by the time direction values and the frequency direction values of the plurality of pilot symbols. The central symbol preferably has a frequency direction value equal to the frequency direction values of two of the plurality of pilot symbols, and has a time direction value midway between the time direction values of the two pilot symbols having the same frequency direction value as the central symbol. This can generally be described as a four-point 2-D interpolation of the channel response between pilot symbols. Third, the channel estimator **72** smoothes the channel responses (corresponding to both encoded pilot symbols and to the central symbol) in the frequency direction, preferably by performing a three-point smoothing, as per step **505**. Fourth, the channel estimator **72** performs an interpolation in the frequency direction to estimate the channel response for remaining symbols, as per step **506**. The interpolation may be a linear interpolation for symbols having a frequency direction value equal to a first or a last useful sub-carrier within the OFDM symbol, and a cubic Lagrange interpolation otherwise.

The method of inserting pilot symbols (described above with reference to FIG. **4**) and the channel estimation method (described above with reference to FIG. **10**) need not be used together. Any channel estimation method may be used by the OFDM receiver to estimate the channel responses for an OFDM frame containing encoded pilot symbols inserted using the method described above. However, due to the sparse distribution of the pilot symbols in the pilot pattern described above with reference to FIG. **4** and FIG. **5**, a two-dimensional interpolation method is preferable over a one-dimensional interpolation method. Similarly, the channel estimation method may be applied to an OFDM frame containing any pattern of pilot symbols.

The invention has been described with respect to an MIMO-OFDM communication system. The invention may also be used with advantage in a single input-multiple output OFDM communication system, as the method of inserting pilot symbols (described with reference to FIG. **4**) and the channel estimation method (described with reference to FIG. **10**) do not depend on the number of receiving antenna. Each receiving antenna within the OFDM receiver **50** performs channel estimation independently, regardless of the number of receiving antennae present.

The channel estimation method described with reference to FIG. **10** will also be advantageous in an OFDM communication system having only one transmitting antenna, as the method provides an improved interpolation of the channel response regardless of the number of transmitting antenna. The method of inserting pilot symbols described with reference to FIG. **11** may be used in an OFDM communication system having only one transmitting antenna, but will not be as advantageous as in an OFDM communication system having more than one transmitting antenna as there will be no reduction in overhead.

The method of inserting pilot symbols and the channel estimation method are preferably implemented on the OFDM transmitter and on the OFDM receiver respectively in the form of software instructions readable by a digital signal processor. Alternatively, the methods may be implemented as

logic circuitry within an integrated circuit. More generally, any computing apparatus containing logic for executing the described functionality may implement the methods. The computing apparatus which implements the methods (in particular the pilot inserter or the channel estimator) may be a single processor, more than one processor, or a component of a larger processor. The logic may comprise external instructions stored on a computer-readable medium, or may comprise internal circuitry.

What has been described is merely illustrative of the application of the principles of the invention. Other arrangements and methods can be implemented by those skilled in the art without departing from the spirit and scope of the present invention.

We claim:

1. A method of transmitting symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames at an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain, and a plurality of sub-carriers in the frequency domain, the method comprising the steps of:

transmitting, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

transmitting, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

2. The method of claim **1**, further comprising transmitting the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

3. The method of claim **1**, wherein the first and second codes are space time block codes.

4. The method of claim **1**, further comprising applying an inverse fast Fourier transform to the pilot symbols.

5. The method of claim **1**, wherein the scattered pattern is a diamond lattice pattern.

6. The method of claim **1**, further comprising transmitting data symbols from the first and second antenna of the OFDM transmitter.

7. The method of claim **1**, wherein the scattered pattern is scattered in time and frequency.

8. The method of claim **1**, wherein each OFDM frame includes a preamble.

9. A device for transmitting pilot symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames at an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain, and a plurality of sub-carriers in the frequency domain, comprising:

a first antenna of the OFDM transmitter;

a second antenna of the OFDM transmitter; and

one or more processors configured to:

cause transmission via the first antenna, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

cause transmission via the second antenna, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

10. The device of claim **9**, the one or more processors further configured to cause transmission of the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

11. The device of claim **9**, wherein the first and second codes are space time block codes.

12. The device of claim **9**, the one or more processors further configured to apply an inverse fast Fourier transform to the pilot symbols.

13. The device of claim **9**, wherein the scattered pattern is a diamond lattice pattern.

14. The device of claim **9**, the one or more processors further configured to cause transmission of data symbols from the first and second antenna of the OFDM transmitter.

15. The device of claim **9**, wherein the scattered pattern is scattered in time and frequency.

16. The device of claim **9**, wherein each OFDM frame includes a preamble.

17. A non-transitory computer readable medium for transmitting symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames at an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers in the frequency domain, the computer readable medium storing instructions to cause a processor to perform operations comprising:

transmitting, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

transmitting, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

18. The computer readable medium of claim **17**, the operations further comprising transmitting the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

19. The computer readable medium of claim **17**, wherein the first and second codes are space time block codes.

20. The computer readable medium of claim **17**, the operations further comprising applying an inverse fast Fourier transform to the pilot symbols.

21. The computer readable medium of claim **17**, wherein the scattered pattern is a diamond lattice pattern.

22. The computer readable medium of claim **17**, the operations further comprising transmitting data symbols from the first and second antenna of the OFDM transmitter.

23. The computer readable medium of claim **17**, wherein the scattered pattern is scattered in time and frequency.

24. The computer readable medium of claim **17**, wherein each OFDM frame includes a preamble.

25. A method for receiving symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames transmitted from an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers in the frequency domain, the method comprising the steps of:

receiving, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

receiving, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna

correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

26. The method of claim **25**, further comprising receiving the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

27. The method of claim **25**, wherein the first and second codes are space time block codes.

28. The method of claim **25**, further comprising estimating a channel based on the received pilot symbols.

29. The method of claim **25**, wherein the scattered pattern is a diamond lattice pattern.

30. The method of claim **25**, further comprising receiving data symbols from the first and second antenna of the OFDM transmitter.

31. A User Equipment (UE) for receiving pilot symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames transmitted from an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers in the frequency domain, comprising:

a receiver configured to:

receive, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

receive, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

32. The device of claim **31**, the receiver further configured to receive the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

33. The device of claim **31**, wherein the first and second codes are space time block codes.

34. The device of claim **31**, the UE further comprises a processor configured to estimate a channel based on the received pilot symbols.

35. The device of claim **31**, wherein the scattered pattern is a diamond lattice pattern.

36. The device of claim **31**, the receiver further configured to transmit data symbols from the first and second antenna of the OFDM transmitter.

37. A non-transitory computer readable medium for receiving symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames transmitted from an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers in the frequency domain, the computer readable medium storing instructions to cause a processor to perform operations comprising:

receiving, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and

receiving, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.

38. The computer readable medium of claim **37**, the operations further comprising receiving the pilot symbols with a power level which is dynamically adjusted as a function of a modulation type applied to the sub-carriers carrying data.

39. The computer readable medium of claim **37**, wherein the first and second codes are space time block codes.

40. The computer readable medium of claim **37**, the operations further comprising estimating a channel based on the received pilot symbols.

41. The computer readable medium of claim **37**, wherein the scattered pattern is a diamond lattice pattern.

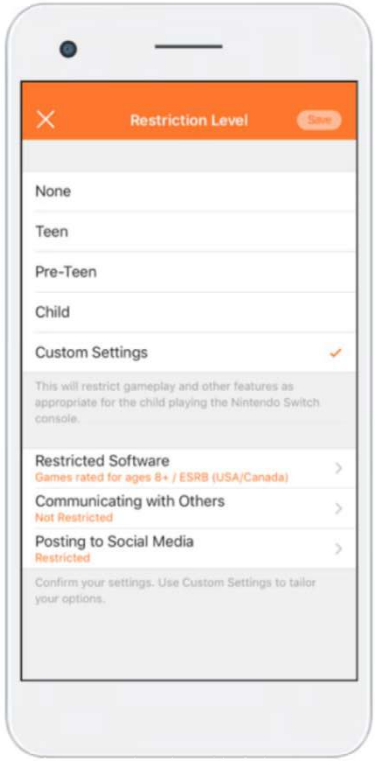
42. The computer readable medium of claim **37**, the instructions further comprising receiving data symbols from the first and second antenna of the OFDM transmitter.

* * * * *

EXHIBIT G

Exhibit G – U.S. Patent No. 9,542,571

Claims	Identification
10[pre]: A device, comprising:	To the extent the preamble is limiting, Nintendo-branded devices are devices comprising the following limitations. General information The parental controls for Nintendo Switch allow you to manage which features and games your child can use on their system. Setting up parental controls allows you to set restrictions through the Nintendo Switch console or with the more extensive Nintendo Switch Parental Controls smart device app. You can also set restrictions for Nintendo eShop through your Nintendo Account. • Parental controls can restrict the download and use of certain content, set play time limits, and restrict the use of certain features on Nintendo Switch. • Parental controls are set for the system - not the user. Once set, the same restrictions will be in place for everyone that uses the system. • The parent/guardian chooses a PIN number (between 4 and 8 digits long) when setting up the parental controls. The PIN will be used in the future whenever a restriction needs to be bypassed or changed. • Parental controls can also be managed on your smart device, via the Nintendo Switch Parental Controls application. Some features (such as play time limits) can only be managed through the smart device application. Please note that an Internet connection is required to use this feature. *See, e.g.*, *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508.

Claims	Identification
	  *See, e.g.*, *Nintendo Switch Parental Controls mobile app*, Nintendo, https://www.nintendo.com/us/switch/parental-controls/; *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo Customer Support, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508; *How to Set Up, Adjust, or Remove Nintendo Switch Parental Controls*, Nintendo Customer Support, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22447; *Nintendo Switch™*, Entertainment Software Rating Board, https://www.esrb.org/tools-for-parents/parental-controls/nintendo-switch/.
10[b] a memory; and	Nintendo-branded devices include a memory. Nintendo Switch™ - OLED Model  [. . .] CPU/GPU — NVIDIA Custom Tegra processor

Claims	Identification

Nintendo Switch™ console (HAC-001(-01))

[. . .]

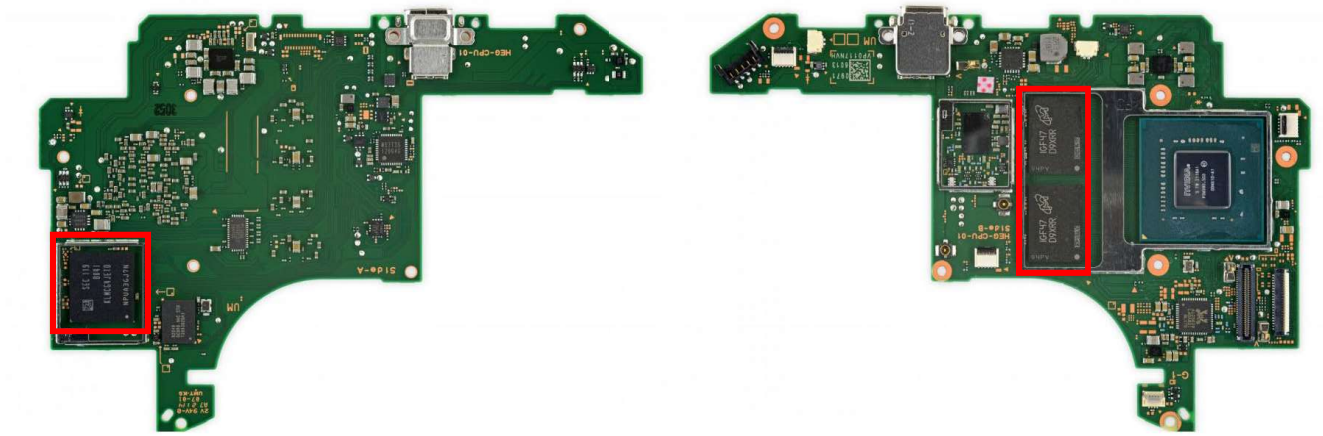
CPU/GPU	NVIDIA Custom Tegra processor

Nintendo Switch Lite (HDH-001)

[. . .]

CPU/GPU	NVIDIA Custom Tegra processor

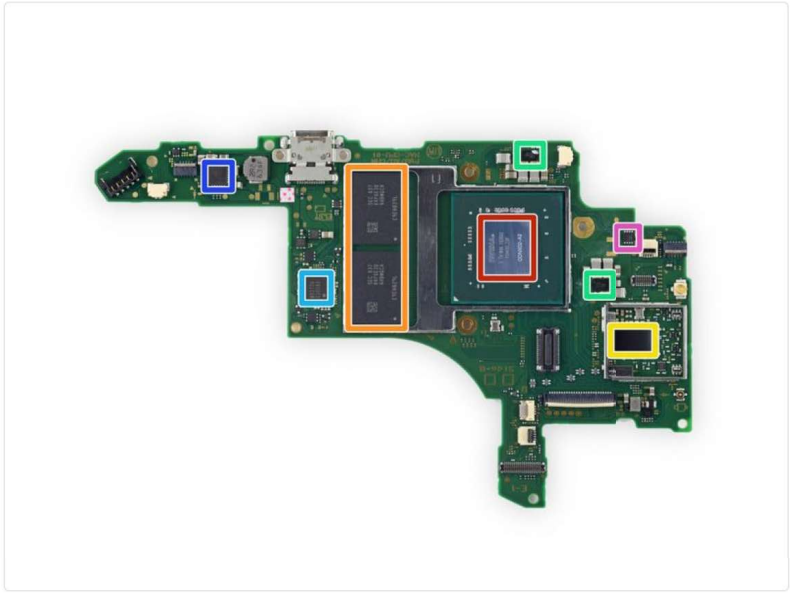
See, e.g., *Nintendo Switch Technical Specs*, Nintendo, https://www.nintendo.com/us/switch/tech-specs/.

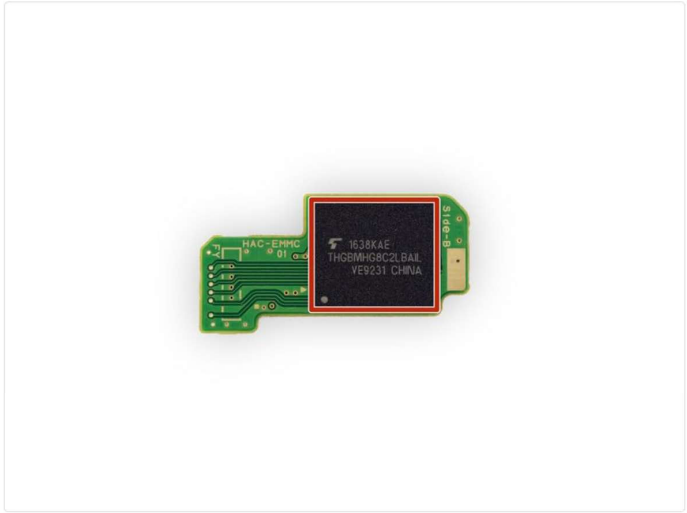


Silicon-wise, we see a lot of similarities to Switches past, with the main differences being:

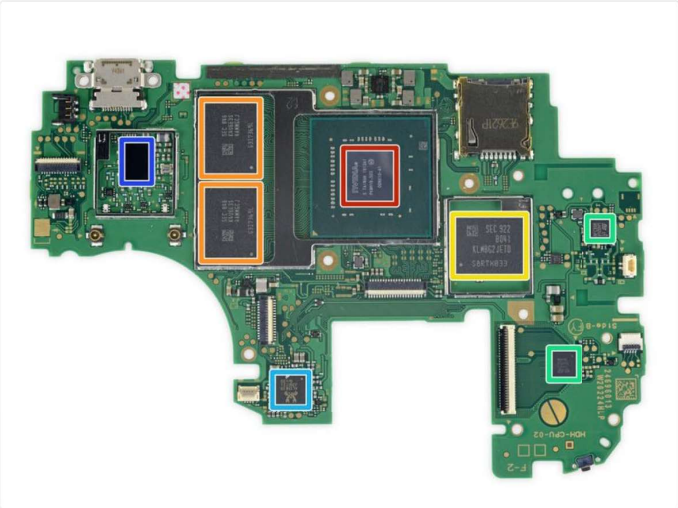
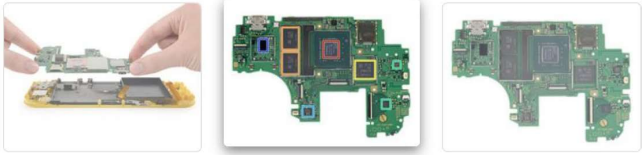
- Accelerometer made by TDK-Invensense instead of STMicroelectronics
- LPDDR4 Memory made by Micron instead of Samsung
- NAND Flash made by Samsung instead of Toshiba

Claims	Identification

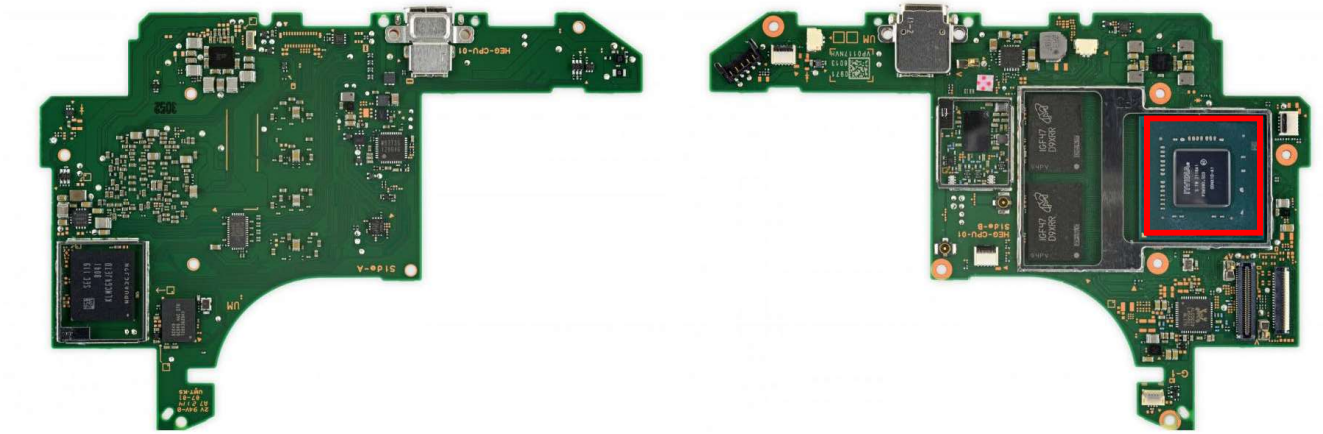
	See, e.g., Sam Goldheart, *Nintendo Switch OLED Teardown: More Than Screen Deep*, IFIXIT (Oct. 13, 2021), https://www.ifixit.com/News/53272/nintendo-switch-oled-teardown-more-than-screen-deep.
	Step 11
	Edit
	 
	• A small gathering of ~~Miis~~ ICs populates the front side of the motherboard:
	  • NVIDIA ODNX02-A2 (presumably the Tegra X1-based SoC)
	  • Samsung K4F6E304HB-MGCH 2 GB LPDDR4 DRAM (x2 for a total of 4 GB)
	  • Broadcom/Cypress BCM4356 802.11ac 2×2 + Bluetooth 4.1 SoC
	  • Maxim Integrated MAX77621AEWI+T three phase buck regulator (x2)
	  • Rohm BM92T36 USB-C controller
	  • Texas Instruments BQ24193 single cell battery charger (possibly)
	  • Texas Instruments TMP451 remote/local temperature sensor

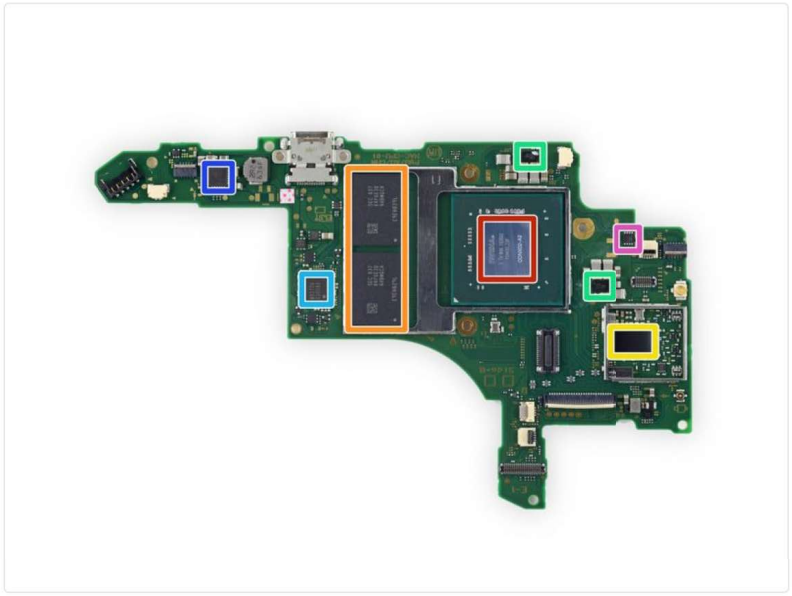
Claims	Identification
	Step 10   • This is a well-connected motherboard; to get it free, we pop off the digitizer, backlight, and speaker connectors, two antennas, *and* the two Joy-Con rails. And then remove six Phillips screws. • But hey, that's some awesome modularity. Even the eMMC storage pops off with an independent PCB! • Nintendo made a 6.2" tablet with removable flash storage, so don't say it can't be done. • The storage board contains a single Toshiba THGBMHG8C2LBAIL 32 GB eMMC NAND Flash IC. • Sadly, the modularity ends at the USB-C port. This high-wear component will require some intense soldering skills to replace. *See, e.g.*, Evan Noronha et al., *Nintendo Switch Teardown*, IFIXIT (Mar. 3, 2017), https://www.ifixit.com/Teardown/Nintendo+Switch+Teardown/78263.

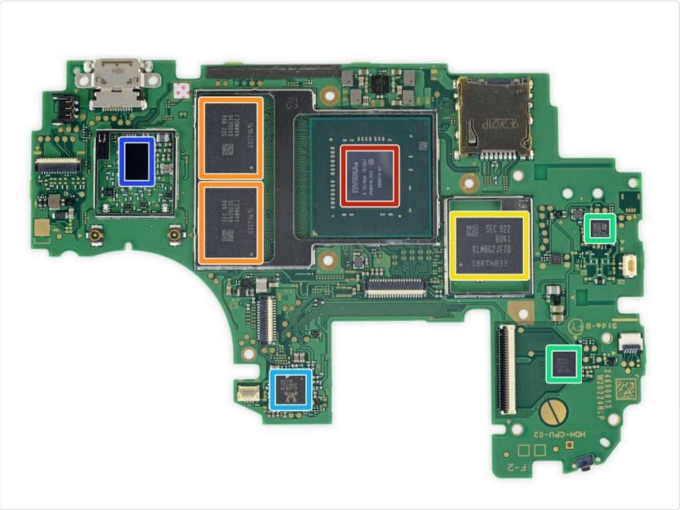
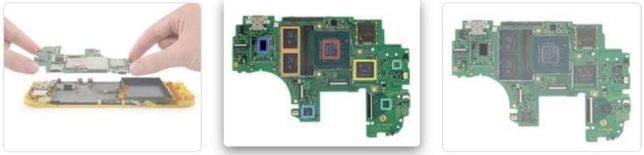
Claims	Identification

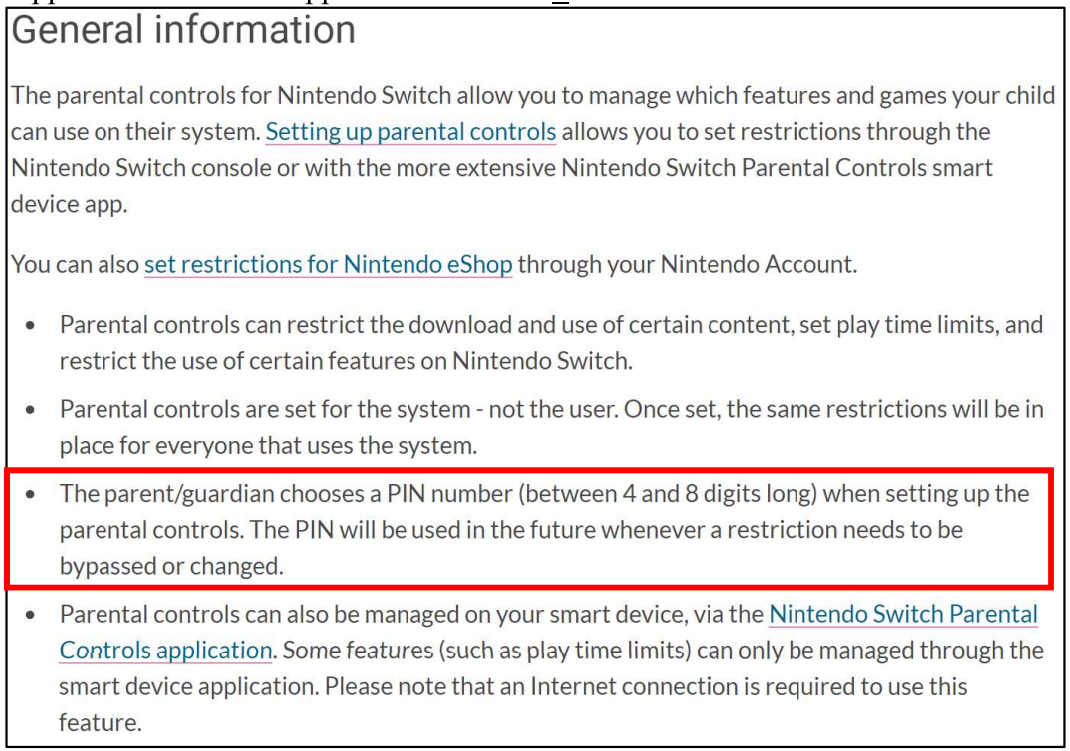
	Step 8
	 
	 
	• Removing the board, we note that the formerly modular flash storage is also now soldered down. (DIY storage swaps in the original Switch didn't *work*, but were at least physically possible.)
	• Side A of this silicon capybara:
	  • Nvidia ODNX10-A1 (Tegra X1-based SoC, presumably a custom riff on the T210B01 variant)
	  • 2x Samsung K4U6E3S4AM-MGCJ LPDDR4X DRAM 16 Gb (4 GB total)
	  • Samsung KLMBG2JETD-B041 32 GB eMMC flash storage
	  • ST Microelectronics ST21NFCD NFC controller and FingerTip touch screen controller
	  • Realtek ALC5639 audio codec
	  • Cypress CYW4356X 802.11ac Wi-Fi + Bluetooth 5.0 SoC
	See, e.g., Jeff Suovanen et al., *Nintendo Switch Lite Teardown*, IFIXIT (Sept. 24, 2019), https://www.ifixit.com/Teardown/Nintendo+Switch+Lite+Teardown/126223.

10[b] a processor coupled with the memory and configured by instructions stored in the memory to:	Nintendo-branded devices include a processor coupled with the memory and configured by instructions stored in the memory to perform the following steps. Nintendo Switch™ - OLED Model [redacted] [. . .] Storage: 64 GB Users can easily expand storage space using microSDHC or microSDXC cards up to 2TB (sold separately).

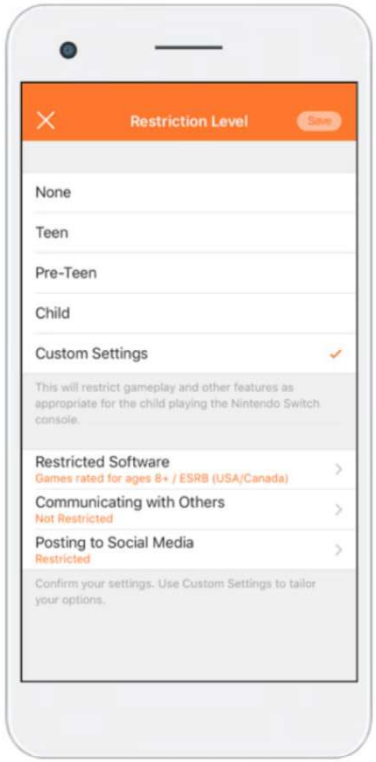
Claims	Identification
	Nintendo Switch™ console (HAC-001(-01))  [. . .] Storage: 32 GB of internal storage, a portion of which is reserved for use by the system. Users can easily expand storage space using microSDHC or microSDXC cards up to 2TB (sold separately). Nintendo Switch Lite (HDH-001)  [. . .] Storage: 32 GB of internal storage, a portion of which is reserved for use by the system. Users can easily expand storage space using microSDHC or microSDXC cards up to 2TB (sold separately). *See, e.g.*, *Nintendo Switch Technical Specs*, Nintendo, https://www.nintendo.com/us/switch/tech-specs/.  *See, e.g.*, Sam Goldheart, *Nintendo Switch OLED Teardown: More Than Screen Deep*, IFIXIT (Oct. 13, 2021), https://www.ifixit.com/News/53272/nintendo-switch-oled-teardown-more-than-screen-deep.

Claims	Identification
	Step 11  Edit • A small gathering of ~~Miis~~ ICs populates the front side of the motherboard: • NVIDIA ODNX02-A2 (presumably the Tegra X1-based SoC) • Samsung K4F6E304HB-MGCH 2 GB LPDDR4 DRAM (x2 for a total of 4 GB) • Broadcom/Cypress BCM4356 802.11ac 2×2 + Bluetooth 4.1 SoC • Maxim Integrated MAX77621AEWI+T three phase buck regulator (x2) • Rohm BM92T36 USB-C controller • Texas Instruments BQ24193 single cell battery charger (possibly) • Texas Instruments TMP451 remote/local temperature sensor *See, e.g.*, Evan Noronha et al., *Nintendo Switch Teardown*, IFIXIT (Mar. 3, 2017), https://www.ifixit.com/Teardown/Nintendo+Switch+Teardown/78263.

Claims	Identification
	Step 8   • Removing the board, we note that the formerly modular flash storage is also now soldered down. (DIY storage swaps in the original Switch didn't *work*, but were at least physically possible.) • Side A of this silicon capybara: • Nvidia ODNX10-A1 (Tegra X1-based SoC, presumably a custom riff on the T210B01 variant) • 2x Samsung K4U6E3S4AM-MGCJ LPDDR4X DRAM 16 Gb (4 GB total) • Samsung KLMBG2JETD-B041 32 GB eMMC flash storage • ST Microelectronics ST21NFCD NFC controller and FingerTip touch screen controller • Realtek ALC5639 audio codec • Cypress CYW4356X 802.11ac Wi-Fi + Bluetooth 5.0 SoC *See, e.g.*, Jeff Suovanen et al., *Nintendo Switch Lite Teardown*, IFIXIT (Sept. 24, 2019), https://www.ifixit.com/Teardown/Nintendo+Switch+Lite+Teardown/126223.
10[c]: receive owner information from an owner of the device;	Nintendo-branded devices receive owner information from an owner of the device. Forgot Parental Controls PIN on Nintendo Switch Applies to: Nintendo Switch Family, Nir … del Parental controls can be set directly on the Nintendo Switch system or through the Nintendo Switch Parental Controls app for smart devices. The person who initially sets the parental controls selects a 4-8 digit PIN number, which is required to adjust or change settings in the future. Follow these steps to locate or reset the parental controls PIN ⓘ for Nintendo Switch.

Claims	Identification
	See, e.g., *Forgot Parental Controls PIN on Nintendo Switch*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22299/.  *See, e.g.*, *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508.

Claims	Identification
	Complete these steps 1. Log in to your existing parent/guardian Nintendo Account to access your Nintendo Account settings. • Only a parent/guardian Nintendo Account in a Nintendo family group can set Nintendo eShop purchase restrictions. 2. Click **Family group** to see a list of all supervised accounts ⓘ in the family group. 3. Click the Nintendo Account where you want to manage restrictions. 4. Click each setting that you want to adjust: • **Spending/purchases on Nintendo Switch eShop and nintendo.com** Check the box to disable purchases and auto-renewal options on Nintendo Switch AND through the My Nintendo Store (including physical orders). • **Viewing of content on Nintendo Switch eShop** Check **Restrict** to restrict the content that can be seen on the Nintendo eShop on Nintendo Switch. Content will automatically be restricted based on the player's age. 5. Click **Save changes** to confirm the change. *See, e.g.*, *How to Set Nintendo eShop Restrictions*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22444.

Claims	Identification
10[d]: receive owner control information that comprises: a list of applications permitted for installation on the device, and permissions associated with each permitted application in the list of applications;	Nintendo-branded devices receive owner control information that comprises a list of applications permitted for installation on the electronic device, and permissions associated with each permitted application in the list of applications.   *See, e.g.*, *Nintendo Switch Parental Controls mobile app*, Nintendo, https://www.nintendo.com/us/switch/parental-controls/; *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo Customer Support, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508; *How to Set Up, Adjust, or Remove Nintendo Switch Parental Controls*, Nintendo Customer Support, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22447; *Nintendo Switch™*, Entertainment Software Rating Board, https://www.esrb.org/tools-for-parents/parental-controls/nintendo-switch/.

Claims	Identification

General information

The parental controls for Nintendo Switch allow you to manage which features and games your child can use on their system. Setting up parental controls allows you to set restrictions through the Nintendo Switch console or with the more extensive Nintendo Switch Parental Controls smart device app.

You can also set restrictions for Nintendo eShop through your Nintendo Account.

- Parental controls can restrict the download and use of certain content, set play time limits, and restrict the use of certain features on Nintendo Switch.

[. . .]

Features and settings that can be restricted through Parental Controls

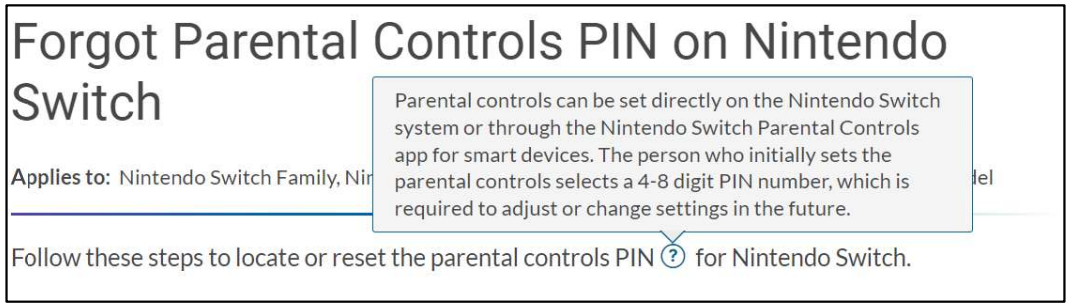
Categories	Nintendo Switch system	Smart device app	Nintendo Account
Software by age rating	✔	✔	⊘
Posting to social media	✔	✔	⊘
Communication with others	✔	✔	⊘
VR Mode (3D Visuals)	✔	✔	⊘
Play-time limits	⊘	✔	⊘
View play activity	⊘	✔	⊘
Purchase restrictions	⊘	⊘	✔
Disable Friend Suggestions	⊘	⊘	✔
Manage info shared with 3rd parties	⊘	⊘	✔

[. . .]

Claims	Identification
	What are the preset parental control restriction levels on Nintendo Switch? When setting up parental controls for Nintendo Switch, you can choose from the following preset restriction levels (or customize the restrictions yourself). **Teen** • Restricted Software - Games rated for ages 17+ (games rated Mature by the ESRB) • Posting to Social Media - Not Restricted • Communicating with Others - Not Restricted • Software Rating Organization - Appropriate organization for your region • VR Mode (3D Visuals) - Not Restricted **Pre-Teen** • Restricted Software - Games rated for ages 13+ (games rated Teen and Mature by the ESRB) • Posting to Social Media - Restricted • Communicating with Others - Restricted • Software Rating Organization - Appropriate organization for your region • VR Mode (3D Visuals) - Not Restricted **Child** • Restricted Software - Games rated for ages 8+ (games rated Everyone 10+, Teen and Mature by the ESRB) • Posting to Social Media - Restricted • Communicating with Others - Restricted • Software Rating Organization - Appropriate organization for your region • VR Mode (3D Visuals) - Restricted *See, e.g.*, *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508.

Claims	Identification
	Complete these steps 1. Log in to your existing parent/guardian Nintendo Account to access your Nintendo Account settings. • Only a parent/guardian Nintendo Account in a Nintendo family group can set Nintendo eShop purchase restrictions. 2. Click **Family group** to see a list of all supervised accounts ⓘ in the family group. 3. Click the Nintendo Account where you want to manage restrictions. 4. Click each setting that you want to adjust: • **Spending/purchases on Nintendo Switch eShop and nintendo.com** Check the box to disable purchases and auto-renewal options on Nintendo Switch AND through the My Nintendo Store (including physical orders). • **Viewing of content on Nintendo Switch eShop** Check **Restrict** to restrict the content that can be seen on the Nintendo eShop on Nintendo Switch. Content will automatically be restricted based on the player's age. 5. Click **Save changes** to confirm the change. *See, e.g.*, *How to Set Nintendo eShop Restrictions*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22444.

Claims	Identification
	The main parental controls screen on your app gives you access to many different options, including: 1. "Play-Time Limits" can be set to notify the user if they have exceeded the daily play-time limit. These settings can be set individually by day. ◦ "Play-Time Limit" – restricts the amount of time spent playing games. When the allotted time is up the console will not automatically turn off, but you will have the option to turn off the game remotely via the "Suspend Software" option in the Time Limits window in the app. ◦ "Bedtime Alarm" – allows you to notify your children of when it's time to turn off the console for the evening. 2. "Restriction Level" based on the following parameters: Teen, Pre-Teen, Child, Custom. Selecting "Custom" will allow you to make granular decisions about the content your children will have access to on the Nintendo Switch console: 3. "Restricted Software" – allows you to restrict titles based on the age of your children up to 18+. This will translate to the ESRB rating parameters. For example, if you select 13+, your console will have access to games rated EC (Early Childhood), E (Everyone), E10+ (Everyone 10+) and T (Teen). Playing of captured videos in the Album will follow the same restriction. 4. "Communicating with Others" – allows you to restrict or limit the ability to interact with other players online. This can be set on a game-by-game basis. 5. "Posting Screenshots on Social Networks" – allows you to restrict the ability to post screenshots to social networks like Twitter and Facebook. 6. "Whitelist" – allows you to add specific software titles to the whitelist to exclude them from some Parental Controls restrictions on the Nintendo Switch console. *See, e.g.*, *Nintendo Switch*™, Entertainment Software Rating Board, https://www.esrb.org/tools-for-parents/parental-controls/nintendo-switch/.

Claims	**Identification**
10[e]: store the owner control information in a protected data store to prevent alteration or deletion of the owner control information in response to authenticating the owner control information using the owner information;	Nintendo-branded devices, on information and belief, store the owner control information in a protected data store to prevent alteration or deletion of the owner control information in response to authenticating the owner control information using the owner information;  *See, e.g.*, Forgot Parental Controls PIN on Nintendo Switch, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22299/.

Claims	Identification
	General information The parental controls for Nintendo Switch allow you to manage which features and games your child can use on their system. Setting up parental controls allows you to set restrictions through the Nintendo Switch console or with the more extensive Nintendo Switch Parental Controls smart device app. You can also set restrictions for Nintendo eShop through your Nintendo Account. • Parental controls can restrict the download and use of certain content, set play time limits, and restrict the use of certain features on Nintendo Switch. • Parental controls are set for the system - not the user. Once set, the same restrictions will be in place for everyone that uses the system. • The parent/guardian chooses a PIN number (between 4 and 8 digits long) when setting up the parental controls. The PIN will be used in the future whenever a restriction needs to be bypassed or changed. • Parental controls can also be managed on your smart device, via the Nintendo Switch Parental Controls application. Some features (such as play time limits) can only be managed through the smart device application. Please note that an Internet connection is required to use this feature. [. . .]

Claims	Identification

Features and settings that can be restricted through Parental Controls

Categories	Nintendo Switch system	Smart device app	Nintendo Account
Software by age rating	✔	✔	⊘
Posting to social media	✔	✔	⊘
Communication with others	✔	✔	⊘
VR Mode (3D Visuals)	✔	✔	⊘
Play-time limits	⊘	✔	⊘
View play activity	⊘	✔	⊘
Purchase restrictions	⊘	⊘	✔
Disable Friend Suggestions	⊘	⊘	✔
Manage info shared with 3rd parties	⊘	⊘	✔

[. . .]

What are the preset parental control restriction levels on Nintendo Switch?

When setting up parental controls for Nintendo Switch, you can choose from the following preset restriction levels (or customize the restrictions yourself).

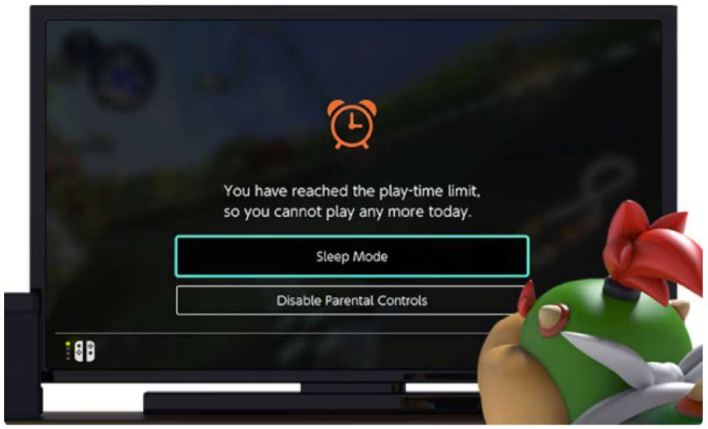
Teen

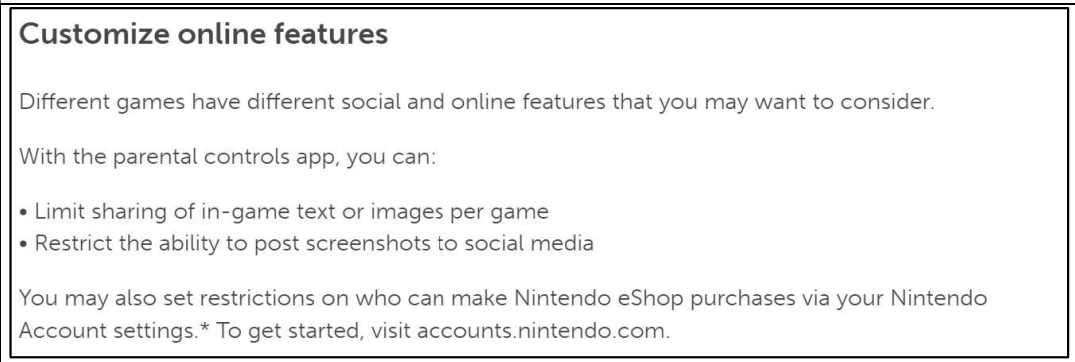
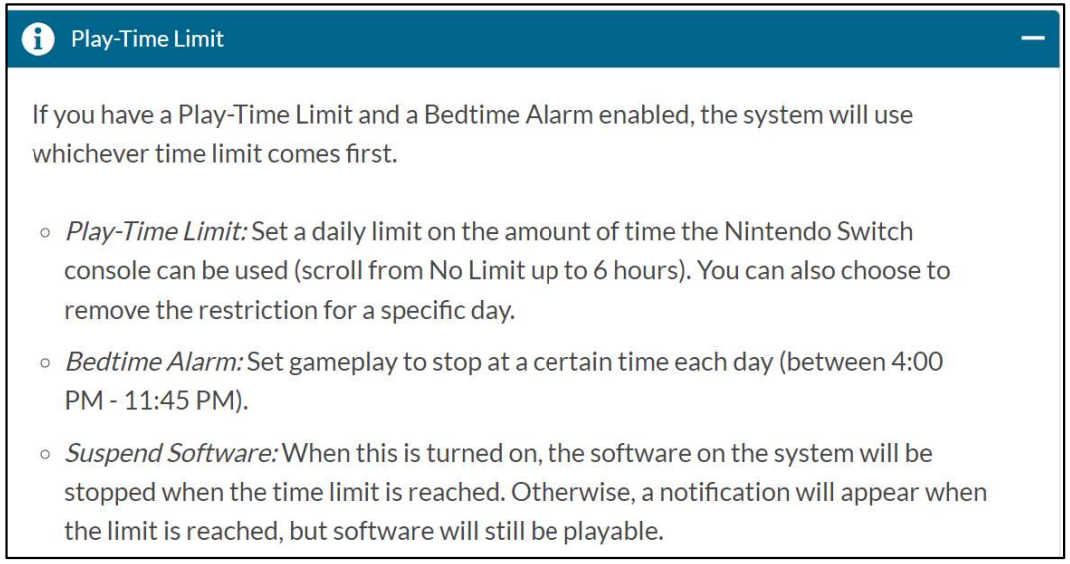
- Restricted Software - Games rated for ages 17+ (games rated Mature by the ESRB)
- Posting to Social Media - Not Restricted
- Communicating with Others - Not Restricted
- Software Rating Organization - Appropriate organization for your region
- VR Mode (3D Visuals) - Not Restricted

Claims	Identification
	Pre-Teen • Restricted Software - Games rated for ages 13+ (games rated Teen and Mature by the ESRB) • Posting to Social Media - Restricted • Communicating with Others - Restricted • Software Rating Organization - Appropriate organization for your region • VR Mode (3D Visuals) - Not Restricted **Child** • Restricted Software - Games rated for ages 8+ (games rated Everyone 10+, Teen and Mature by the ESRB) • Posting to Social Media - Restricted • Communicating with Others - Restricted • Software Rating Organization - Appropriate organization for your region • VR Mode (3D Visuals) - Restricted *See, e.g.*, *Parental Controls Overview/FAQ (Nintendo Switch)*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22508.

Claims	Identification
	Complete these steps 1. Log in to your existing parent/guardian Nintendo Account to access your Nintendo Account settings. • Only a parent/guardian Nintendo Account in a Nintendo family group can set Nintendo eShop purchase restrictions. 2. Click **Family group** to see a list of all supervised accounts ⓘ in the family group. 3. Click the Nintendo Account where you want to manage restrictions. 4. Click each setting that you want to adjust: • **Spending/purchases on Nintendo Switch eShop and nintendo.com** Check the box to disable purchases and auto-renewal options on Nintendo Switch AND through the My Nintendo Store (including physical orders). • **Viewing of content on Nintendo Switch eShop** Check **Restrict** to restrict the content that can be seen on the Nintendo eShop on Nintendo Switch. Content will automatically be restricted based on the player's age. 5. Click **Save changes** to confirm the change. *See, e.g.*, *How to Set Nintendo eShop Restrictions*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22444.

Claims	Identification
	The main parental controls screen on your app gives you access to many different options, including: 1. "Play-Time Limits" can be set to notify the user if they have exceeded the daily play-time limit. These settings can be set individually by day. ◦ "Play-Time Limit" – restricts the amount of time spent playing games. When the allotted time is up the console will not automatically turn off, but you will have the option to turn off the game remotely via the "Suspend Software" option in the Time Limits window in the app. ◦ "Bedtime Alarm" – allows you to notify your children of when it's time to turn off the console for the evening. 2. "Restriction Level" based on the following parameters: Teen, Pre-Teen, Child, Custom. Selecting "Custom" will allow you to make granular decisions about the content your children will have access to on the Nintendo Switch console: 3. "Restricted Software" – allows you to restrict titles based on the age of your children up to 18+. This will translate to the ESRB rating parameters. For example, if you select 13+, your console will have access to games rated EC (Early Childhood), E (Everyone), E10+ (Everyone 10+) and T (Teen). Playing of captured videos in the Album will follow the same restriction. 4. "Communicating with Others" – allows you to restrict or limit the ability to interact with other players online. This can be set on a game-by-game basis. 5. "Posting Screenshots on Social Networks" – allows you to restrict the ability to post screenshots to social networks like Twitter and Facebook. 6. "Whitelist" – allows you to add specific software titles to the whitelist to exclude them from some Parental Controls restrictions on the Nintendo Switch console. *See, e.g.*, *Nintendo Switch*™, Entertainment Software Rating Board, https://www.esrb.org/tools-for-parents/parental-controls/nintendo-switch/.

Claims	Identification
10[f]: receive, from an application operating on the electronic device, a request to access local memory on the electronic device; 10[g]: determine whether the application is allowed to access the local memory in response to identifying a permission associated with the application in the owner control information; and 10[h] control application access to the local memory based upon the determining.	Nintendo-branded devices receive, from an application operating on the electronic device, a request to access local memory on the electronic device; determine whether the application is allowed to access the local memory in response to identifying a permission associated with the application in the owner control information; and control application access to the local memory based upon the determining. **Keep an eye on play time** You can set limits on how long or how late the Nintendo Switch console can be used each day. When the time limit has been reached, an alarm notification will pop up on-screen. The app will also tell you if the Nintendo Switch console stays on past this time limit. If needed, you can always set the system to automatically interrupt the game when the time's up. Parents can disable play time alarms and game suspension features temporarily or for a full day using their PIN.  Alarm  Suspend software

Claims	Identification
	 *See, e.g.*, *Nintendo Switch Parental Controls mobile app*, Nintendo, https://www.nintendo.com/us/switch/parental-controls/.  *See, e.g.*, *How to Set Up, Adjust, or Remove Nintendo Switch Parental Controls*, Nintendo Customer Support, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22447.

Claims	Identification
	Complete these steps 1. Log in to your existing parent/guardian Nintendo Account to access your Nintendo Account settings. • Only a parent/guardian Nintendo Account in a Nintendo family group can set Nintendo eShop purchase restrictions. 2. Click **Family group** to see a list of all supervised accounts ⓘ in the family group. 3. Click the Nintendo Account where you want to manage restrictions. 4. Click each setting that you want to adjust: • **Spending/purchases on Nintendo Switch eShop and nintendo.com** Check the box to disable purchases and auto-renewal options on Nintendo Switch AND through the My Nintendo Store (including physical orders). • **Viewing of content on Nintendo Switch eShop** Check **Restrict** to restrict the content that can be seen on the Nintendo eShop on Nintendo Switch. Content will automatically be restricted based on the player's age. 5. Click **Save changes** to confirm the change. *See, e.g.*, *How to Set Nintendo eShop Restrictions*, Nintendo, https://en-americas-support.nintendo.com/app/answers/detail/a_id/22444.

Claims	Identification
	The main parental controls screen on your app gives you access to many different options, including: 1. "Play-Time Limits" can be set to notify the user if they have exceeded the daily play-time limit. These settings can be set individually by day. ◦ "Play-Time Limit" – restricts the amount of time spent playing games. When the allotted time is up the console will not automatically turn off, but you will have the option to turn off the game remotely via the "Suspend Software" option in the Time Limits window in the app. ◦ "Bedtime Alarm" – allows you to notify your children of when it's time to turn off the console for the evening. 2. "Restriction Level" based on the following parameters: Teen, Pre-Teen, Child, Custom. Selecting "Custom" will allow you to make granular decisions about the content your children will have access to on the Nintendo Switch console: 3. "Restricted Software" – allows you to restrict titles based on the age of your children up to 18+. This will translate to the ESRB rating parameters. For example, if you select 13+, your console will have access to games rated EC (Early Childhood), E (Everyone), E10+ (Everyone 10+) and T (Teen). Playing of captured videos in the Album will follow the same restriction. 4. "Communicating with Others" – allows you to restrict or limit the ability to interact with other players online. This can be set on a game-by-game basis. 5. "Posting Screenshots on Social Networks" – allows you to restrict the ability to post screenshots to social networks like Twitter and Facebook. 6. "Whitelist" – allows you to add specific software titles to the whitelist to exclude them from some Parental Controls restrictions on the Nintendo Switch console. *See, e.g.*, *Nintendo Switch*™, Entertainment Software Rating Board, https://www.esrb.org/tools-for-parents/parental-controls/nintendo-switch/.

EXHIBIT H

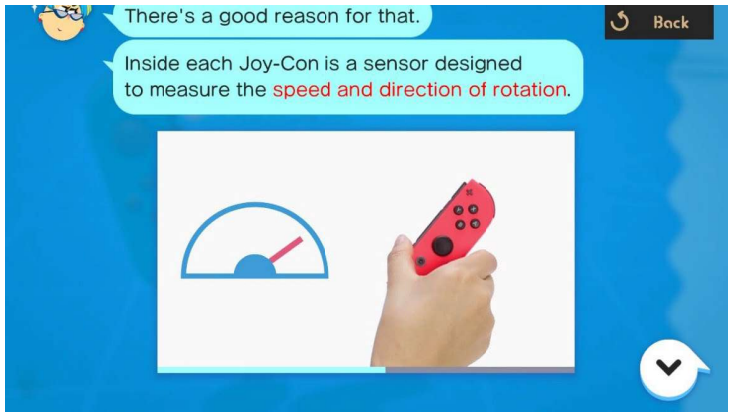
Exhibit H - U.S. Patent No. 8,115,731

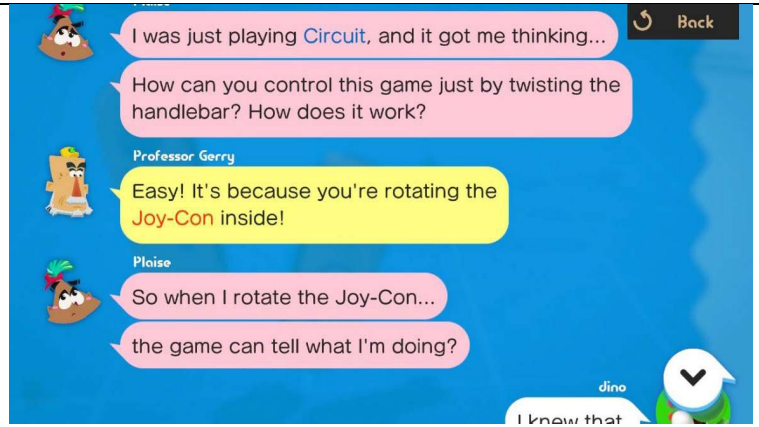
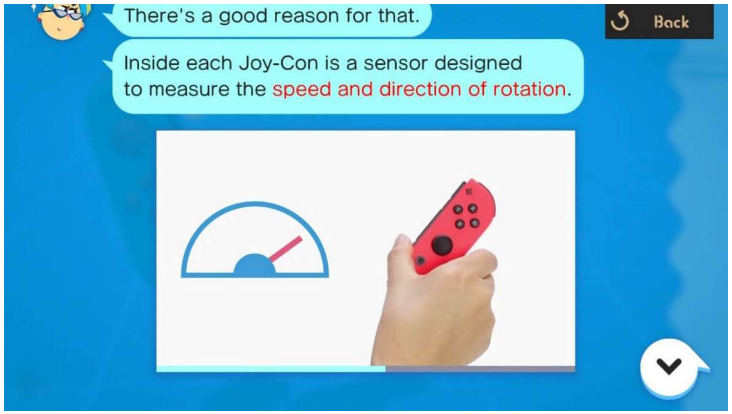
Claims	Identification
1[pre] A handheld computing device, comprising:	To the extent the preamble is limiting, the Nintendo-branded devices include a handheld computing device.   **Handheld Mode** Pick it up and play with the Joy-Con™ controllers attached to enjoy the 6.2" LCD touch screen. Nintendo Store, Switch, *https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/*. **This is Joy-Con!** One controller or two, vertical or sideways, motion controls or buttons... Joy-Con and Nintendo Switch™ give you total gameplay flexibility. Games come to life through easy-to-use motion controls and HD rumble—advanced vibration features built into each Joy-Con. Depending on the game, you might use a single Joy-Con in each hand—or even give the second one to a friend. Includes one Neon Red left Joy-Con, one Neon Blue right Joy-Con, and two Black Joy-Con Straps.  *https://www.nintendo.com/us/store/products/joy-con-set-l-r-neon-red-neon-blue/*

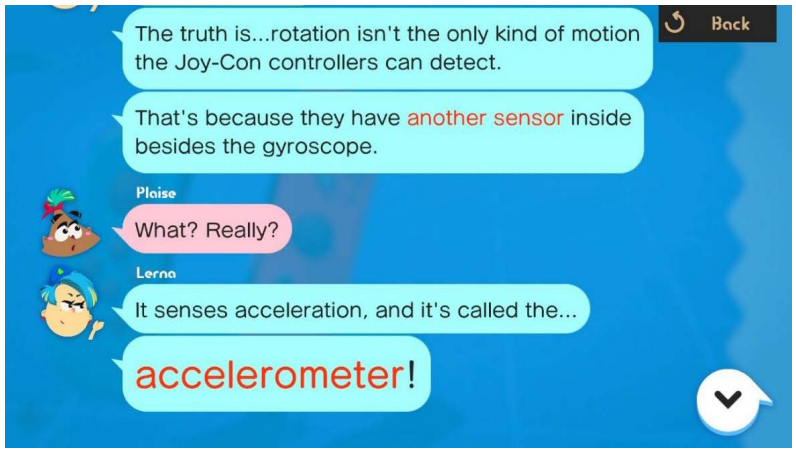
	 *https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/*
1[a] a display;	The Nintendo-branded devices include a display.

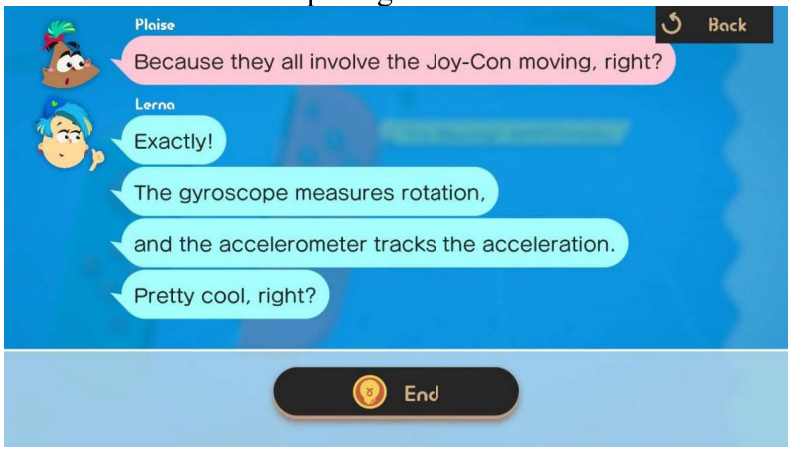
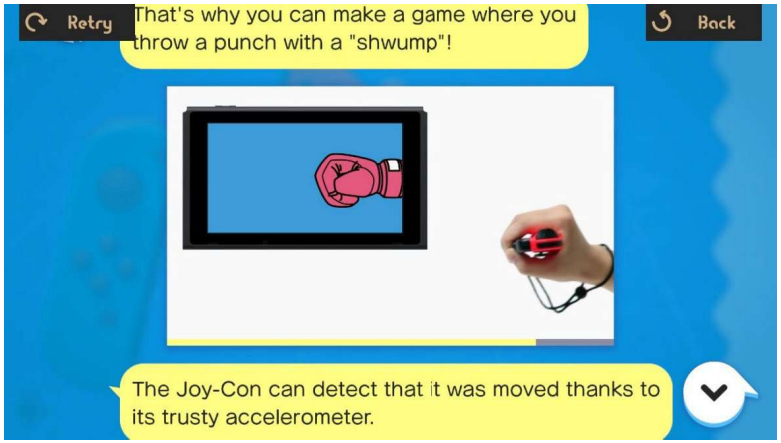
	 *https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/*

	 *https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/*
1[b] an internally located directional input device providing a	The Nintendo-branded devices include an internally located directional input device providing a directional input signal, the directional input signal corresponding to an axis of inclination of the handheld computing device and indicating an orientation.

directional input signal, the directional input signal corresponding to an axis of inclination of the handheld computing device and indicating an orientation;	 *https://www.nintendo.com/us/switch/tech-specs/#joycon-section* The Nintendo Switch with Joy-Con Controller includes an internally located directional input device providing a directional input signal.   Nintendo Labo, Discover Topics. The directional input signal of the Nintendo Switch with Joy-Con Controller corresponds to an axis of inclination of the handheld computing device and indicates an orientation.

	 Nintendo Labo, Discover Topics.  Nintendo Labo, Discover Topics.
1[c] a second directional input device providing a second directional input signal, the second	The Nintendo-branded devices include a second directional input device providing a second directional input signal, the second directional input signal indicating an amount of displacement.

directional input signal indicating an amount of displacement;	 *https://www.nintendo.com/us/switch/tech-specs/#joycon-section* The Nintendo Switch with Joy-Con Controller includes a second directional input device providing a second directional input signal.  Nintendo Labo, Discover Topics.

	The second directional input signal of the Nintendo Switch with Joy-Con Controller indicates an amount of displacement.   Nintendo Labo, Discover Topics.
1[d] a processor coupled to the internally located directional input device and the second directional input device and operable to receive and process the directional input signal in conjunction with the second directional input signal; and	The Nintendo-branded devices include a processor coupled to the internally located directional input device and the second directional input device and operable to receive and process the directional input signal in conjunction with the second directional input signal. The Nintendo-branded devices include a processor coupled to the internally located directional input device and the second directional input device.

Handheld Mode

Pick it up and play with the Joy-Con™ controllers attached to enjoy the 6.2" LCD touch screen.

https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/

CPU/GPU	NVIDIA Custom Tegra processor

https://www.nintendo.com/us/switch/tech-specs/#switch-section

Sensor	**Joy-Con [L]** Accelorometer Gyroscope **Joy-Con [R]** Accelorometer Gyroscope IR Motion Camera

https://www.nintendo.com/us/switch/tech-specs/#joycon-section

	The processor of the Nintendo Switch with Joy-Con Controller is operable to receive and process the directional input signal in conjunction with the second directional input signal.  Nintendo Labo, Discover Topics.
1[e] a memory subsystem, the memory storing an operating system executed by the processor to display on the display a graphical user interface for controlling the operation of the handheld computing device, wherein the graphical user interface provides a graphical element;	The Nintendo-branded devices include a memory subsystem, the memory storing an operating system executed by the processor to display on the display a graphical user interface for controlling the operation of the handheld computing device, wherein the graphical user interface provides a graphical element. The Nintendo-branded devices include a memory subsystem, the memory storing an operating system executed by the processor to display on the display a graphical user interface for controlling the operation of the handheld computing device. **CPU/GPU** — NVIDIA Custom Tegra processor **Storage** — 32 GB of internal storage, a portion of which is reserved for use by the system. Users can easily expand storage space using microSDHC or microSDXC cards up to 2TB (sold separately). *https://www.nintendo.com/us/switch/tech-specs/#switch-section*

Handheld Mode

Pick it up and play with the Joy-Con™ controllers attached to enjoy the 6.2" LCD touch screen.

https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/

Play anytime, anywhere

Get the gaming system that lets you play the games you want, wherever you are, however you like. Bring the full home gaming system experience with you to the park, on an airplane, in a car, or to a friend's apartment.

https://www.nintendo.com/us/store/products/nintendo-switch-neon-blue-neon-red-joy-con-117972/

The graphical user interface provides a graphical element.

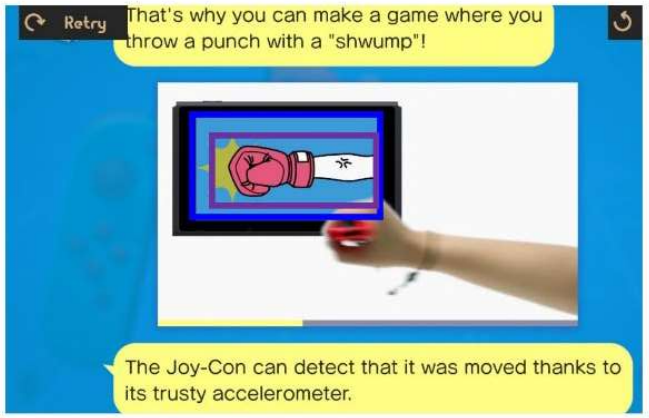
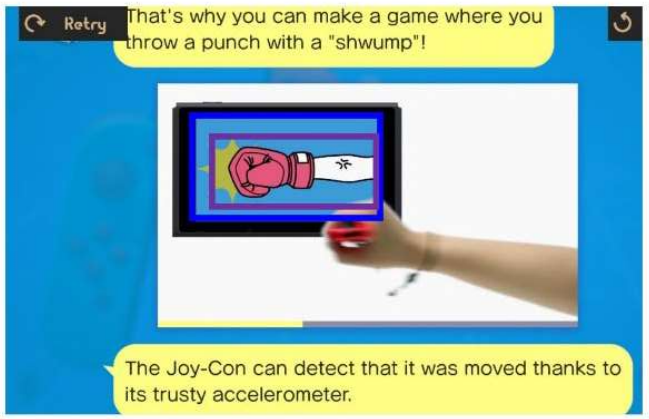
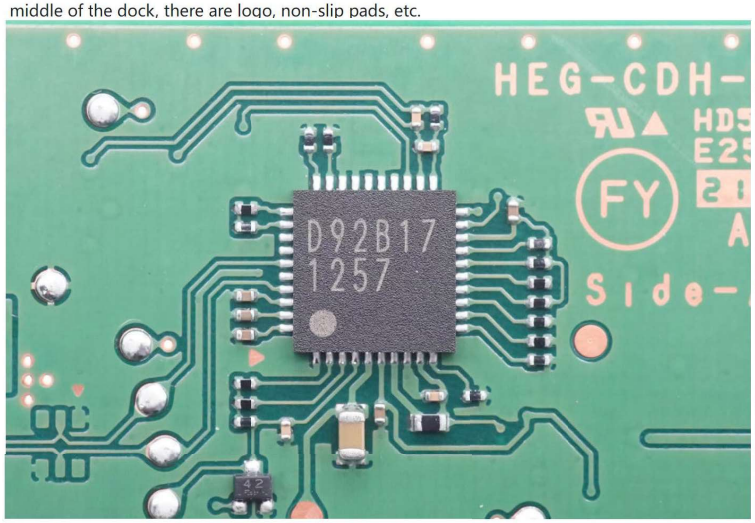
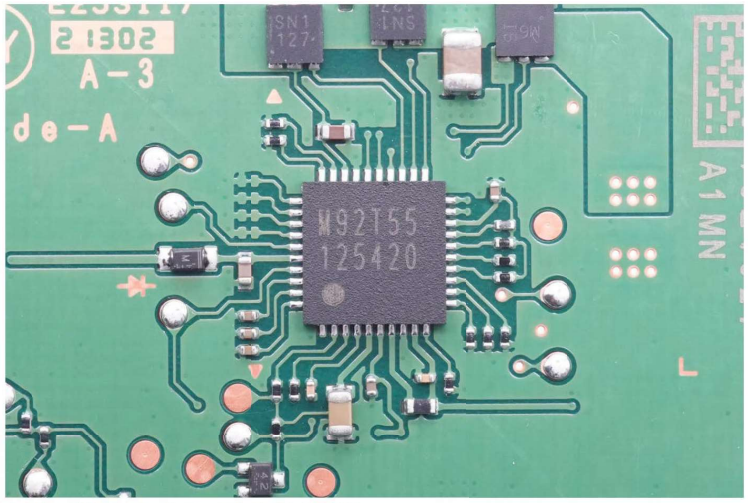
	  Nintendo Labo, Discover Topics.
1[f] wherein the operating system comprises processor-executable instructions that cause the graphical element to move by the amount of displacement in a direction substantially parallel or substantially perpendicular to the orientation.	The operating system of the Nintendo-branded devices comprises processor-executable instructions that cause the graphical element to move by the amount of displacement in a direction substantially parallel or substantially perpendicular to the orientation.   Nintendo Labo, Discover Topics.

EXHIBIT I

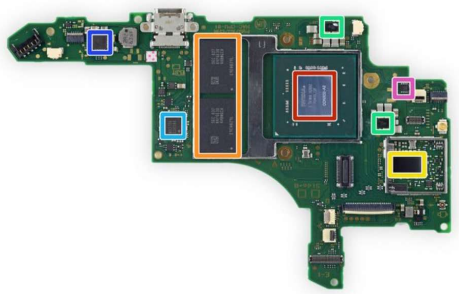
Exhibit I – U.S. Patent No. 8,610,397

Claim	Identification
1[pre] A battery charger for a portable wireless communications device, the portable wireless communications device including a rechargeable battery and a wireless communications transceiver coupled thereto, the portable wireless communications device and rechargeable battery each respectively having a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different rechargeable battery types having respective charging rates, the battery charger comprising:	To the extent the preamble is limiting, Nintendo-branded devices include a battery charger for a portable wireless communications device, the portable wireless communications device including a rechargeable battery and a wireless communications transceiver coupled thereto, the portable wireless communications device and rechargeable battery each respectively having a portable device type and a rechargeable battery type associated therewith from among a plurality of different portable device types and different rechargeable battery types having respective charging rates. Nintendo Switch™ - OLED Model  [. . .] USB connector — USB Type-C Used for charging or for connecting to the Nintendo Switch dock. Nintendo Switch™ console (HAC-001(-01))  [. . .] USB connector — USB Type-C Used for charging or for connecting to the Nintendo Switch dock. Nintendo Switch Lite (HDH-001)  [. . .] USB connector — USB Type-C Used for charging only. *See, e.g.*, *Nintendo Switch Technical Specs*, Nintendo, https://www.nintendo.com/us/switch/tech-specs/.

Claim	Identification
	 The Nintendo Switch OLED charging dock uses a black plastic shell, in addition to the slot in the middle of the dock, there are logo, non-slip pads, etc.  There is a USB-C port in the center of the slot, and the Switch can be charged by placing it in it.  The USB-C controller is from ROHM, marked with D92B17.  Another USB-C controller is marked with M92T55. *See, e.g.*, Joey, *Teardown of Original Nintendo Switch OLED Charging Dock*, ChargerLab (Nov. 9, 2022), https://www.chargerlab.com/teardown-of-original-nintendo-switch-oled-charging-dock/; Sam Goldheart, *Nintendo Switch OLED Teardown: More Than Screen Deep*, IFIXIT (Oct. 13, 2021), https://www.ifixit.com/News/53272/nintendo-switch-oled-teardown-more-than-screen-deep.

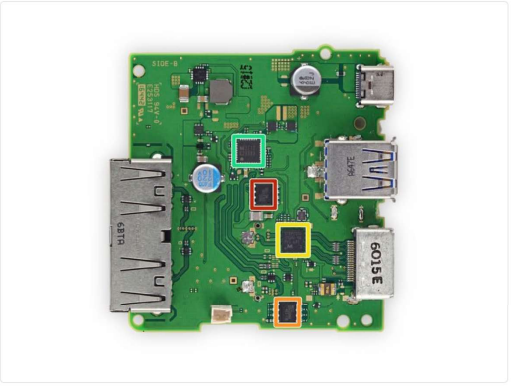
Claim	Identification

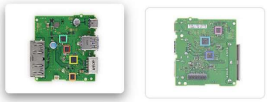
Step 11



- A small gathering of ~~Miis~~ ICs populates the front side of the motherboard:
  - NVIDIA ODNX02-A2 (presumably the Tegra X1-based SoC)
  - Samsung K4F6E304HB-MGCH 2 GB LPDDR4 DRAM (x2 for a total of 4 GB)
  - Broadcom/Cypress BCM4356 802.11ac 2×2 + Bluetooth 4.1 SoC
  - Maxim Integrated MAX77621AEWI+T three phase buck regulator (x2)
  - Rohm BM92T36 USB-C controller
  - Texas Instruments BQ24193 single cell battery charger (possibly)
  - Texas Instruments TMP451 remote/local temperature sensor

Step 23





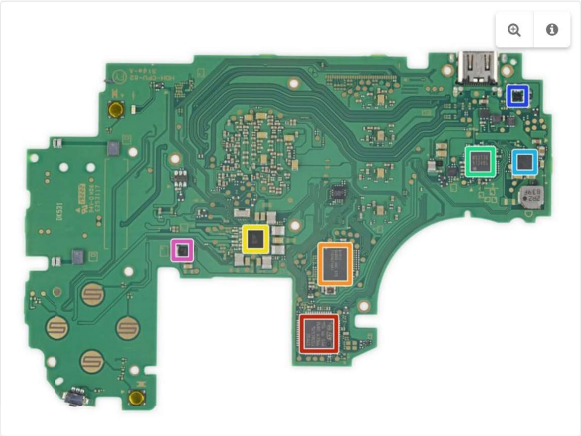
- Dockside ~~fish and~~ chips:
  - Macronix International MX25L512E 512 Kb CMOS flash
  - Macronix International MX25V2006E 2 Mb CMOS flash
  - Megachips STDP2550 Mobility DisplayPort (MyDP) to HDMI Converter
  - Rohm BM92T17 USB-C power delivery controller
  - STMicroelectronics STM32P048 32-bit microcontroller
  - VIA Labs VL210 USB 3.0 Hub Controller
  - Rohm BM92T55 USB-C power delivery controller

Step 23

See, e.g., Evan Noronha et al., *Nintendo Switch Teardown*, IFIXIT (Mar. 3, 2017), https://www.ifixit.com/Teardown/Nintendo+Switch+Teardown/78263.

Claim	Identification

Step 9



- Let's turn that capybara around for some more chips:
  - ST Microelectronics STM32F038C6 32-bit microcontroller w/ 32 KB flash
  - B1913 GCBRG HAC STD T1056719A1 secure MCU (likely)
  - Maxim Integrated MAX77620HEWJ power management IC
  - Rohm BM92T10MWV-Z USB-C power delivery controller
  - Texas Instruments BQ24193 battery charge management
  - Maxim Integrated MAX17050 battery fuel gauge
  - Ricoh RP602Z330C 1.5 A buck-boost regulator

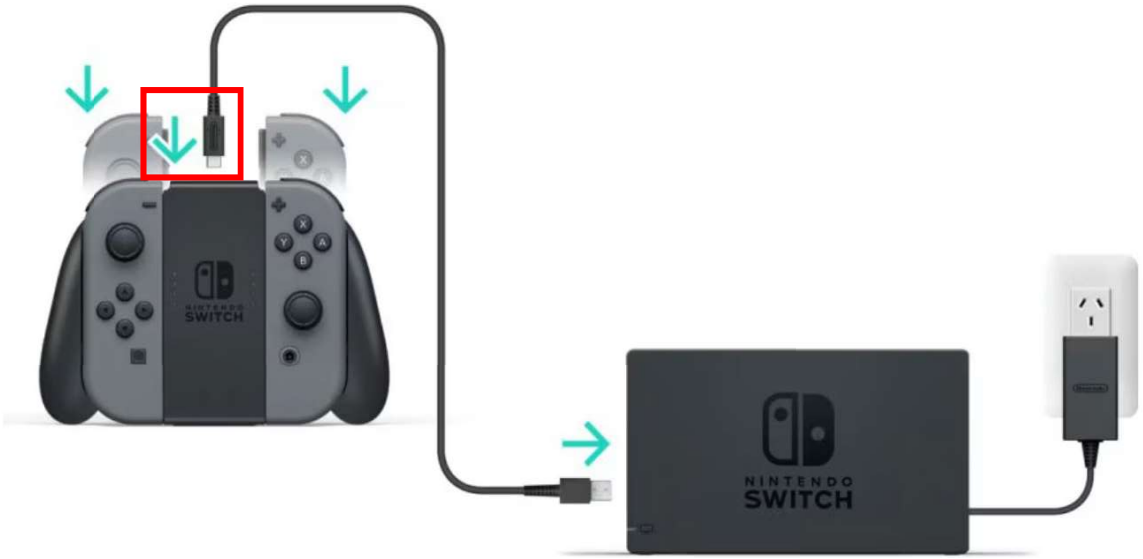
See, e.g., Jeff Suovanen et al., *Nintendo Switch Lite Teardown*, IFIXIT (Sept. 24, 2019), https://www.ifixit.com/Teardown/Nintendo+Switch+Lite+Teardown/126223.

This AC Adapter is the same as the one included with every Nintendo Switch

The screen includes capacitive multi-touch capabilities for compatible games. Battery life can last for more than six hours, but will vary depending on the software and usage conditions. For example, The Legend of Zelda: Breath of the Wild can be played for roughly three hours on a single charge.

While away from home, Nintendo Switch can be charged by plugging the AC adapter into the console's USB Type-C connector.

See, e.g., Nintendo Switch AC Adapter, *Amazon.com*, https://www.amazon.com/Nintendo-Switch-AC-Adapter/dp/B01N7RUZ49/.

Claim	Identification
	While attached to the Joy-Con charging grip. 1. Attach the Joy-Con to the Joy-Con charging grip. 2. Connect the Joy-Con charging grip to the Nintendo Switch dock using the USB cable that was included in the box, or connect it directly to the Nintendo Switch AC adapter (HAC-002).  *See, e.g.*, *How to Charge the Joy-Con Controllers*, Nintendo, https://www.nintendo.com/au/support/articles/how-to-charge-the-joy-con-controllers/; Spawn Wave, *Taking Apart The Nintendo Switch Charge Grip! Is It Worth The Price?*, YouTube (Mar. 4, 2017), https://www.youtube.com/watch?v=qE9EfI19RXo (noting that the device comes with a USB-C cable).

Claim	Identification

Using a Nintendo Switch Pro Controller

In addition to the Joy-Con controllers, you can also play Nintendo Switch with the Pro Controller (sold separately). This controller allows you to play comfortably for longer periods of time when the console is in TV mode or tabletop mode.

When you are using the console in TV mode, you can attach the Pro Controller to the dock with the USB charging cable (HAC-010) to pair or charge it.

When the Pro Controller is done charging, you can disconnect it from the USB charging cable and use it wirelessly.

USB Type-C™ and USB-C™ are trademarks of the USB Implementers Forum.

Specifications:

Compatibility:

- Nintendo Switch (USB-C and Bluetooth)
- PC (USB-C)

Power:

- Lithium-ion battery [CTR-003] battery capacity 1300 mAh
- USB-C connector (recharge)
- Estimated 40-hour battery life

Connectivity:

- Bluetooth
- USB-C

See, e.g., *Using a Nintendo Switch Pro Controller*, Nintendo, https://www.nintendo.com/au/support/articles/nintendo-switch-pro-controller/; Nintendo Switch Pro Controller Repair, IFIXIT, https://www.ifixit.com/Device/Switch_Pro_Controller.

1.1 Overview

This specification defines how USB Devices can negotiate for more current and/or higher or lower voltages over the USB cable (using the USB Type-C CC wire as the communications channel) than are defined in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 1.3]*** or ***[USBBC 1.2]*** specifications. It allows Devices with greater power requirements than can be met with today's specification to get the power they require to operate from V_{BUS} and negotiate with external power sources (e.g. Wall Warts). In addition, it allows a Source and Sink to swap power roles such that a Device could supply power to the Host. For example, a display could supply power to a notebook to charge its battery.

Claim	Identification

To facilitate optimum charging, the specification defines two mechanisms a USB Charger can advertise for the Device to use:

1. A list of fixed voltages each with a maximum current. The Device selects a voltage and current from the list. This is the traditional model used by Devices that use internal electronics to manage the charging of their battery including modifying the voltage and current actually supplied to the battery. The side-effect of this model is that the charging circuitry generates heat that may be problematic for small form factor devices.
2. A list of programmable voltage ranges each with a maximum current (PPS). The Device requests a voltage (in 20 mV increments) that is within the advertised range and a maximum current. The USB Charger delivers the requested voltage until the maximum current is reached at which time the USB charger reduces its output voltage so as not to supply more than the requested maximum current. During the high current portion of the charge cycle, the USB Charger can be directly connected (through an appropriate safety device) to the battery. This model is used by Devices that want to minimize the thermal impact of their internal charging circuitry.

1.2 Purpose

The USB Power Delivery specification defines a power delivery system covering all elements of a USB system including: Hosts, Devices, Hubs, Chargers and cable assemblies. This specification describes the architecture, protocols, power supply behavior, connectors and cabling necessary for managing power delivery over USB at up to 100W. This specification is intended to be fully compatible and extend the existing USB infrastructure. It is intended that this specification will allow system OEMs, power supply and peripheral developers adequate flexibility for product versatility and market differentiation without losing backwards compatibility.

USB Power Delivery is designed to operate independently of the existing USB bus defined mechanisms used to negotiate power which are:

- ***[USB 2.0]***, ***[USB 3.2]*** in band requests for high power interfaces.
- ***[USBBC 1.2]*** mechanisms for supplying higher power (not mandated by this specification).
- ***[USB Type-C 1.3]*** mechanisms for supplying higher power

1.6 Terms and Abbreviations

This section defines terms used throughout this document. For additional terms that pertain to the Universal Serial Bus, see Chapter 2, "Terms and Abbreviations," in ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 1.3]*** and ***[USBBC 1.2]***.

PD	USB Power Delivery
PD Capable	A Port that supports USB Power Delivery.
PD Connection	See Connected.
PD Power (PDP)	The output power of a Source, as specified by the manufacturer and expressed in Fixed Supply PDOs as defined in Section 10.
PDP Rating	Manufacturer declared PDP for a Source.
PDUSB	USB Device Port or USB Host Port that is both PD capable and capable of USB Communication. See also PDUSB Host, PDUSB Device and PDUSB Hub.
PDUSB Device	A USB Device with a PD Capable UFP. A PDUSB Device is only addressed by SOP Packets.

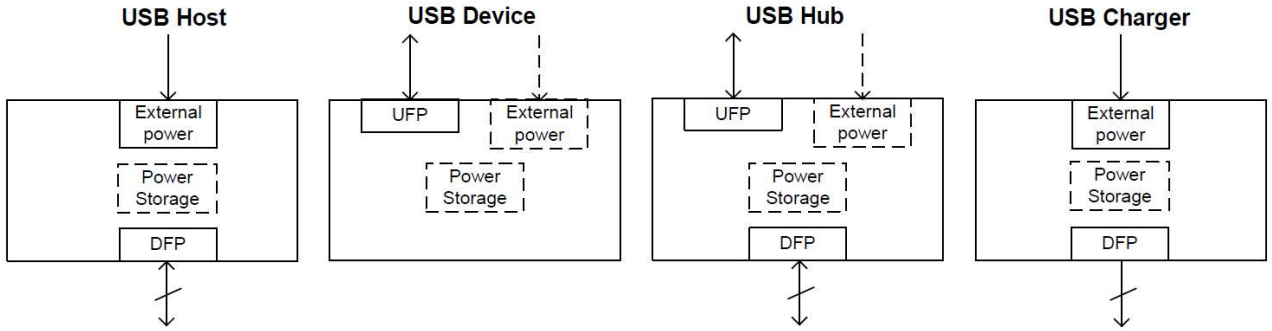
Claim	Identification

PDUSB Host	A USB Host which is PD Capable on at least one of its DFPs. A PDUSB Host is only addressed by SOP Packets.
PDUSB Hub	A port expander USB Device with a UFP and one or more DFPs which is PD Capable on at least one of its Ports. A PDUSB Hub is only addressed by SOP Packets.
PDUSB Peripheral	A USB Device with a PD Capable UFP which is not a PDUSB Hub. A PDUSB Peripheral is only addressed by SOP Packets.
Sink	The Port consuming power from V_{BUS}; most commonly a Device.
Source	A role a Port is currently taking to supply power over V_{BUS}; most commonly a Host or Hub downstream port.
USB Device	Either a hub or a peripheral device as defined in ***[USB 2.0]*** and ***[USB 3.2]***.
USB Host	The host computer system where the USB host controller is installed as defined in ***[USB 2.0]*** and ***[USB 3.2]***.

2.4 USB Power Delivery Capable Devices

Some examples of USB Power Delivery capable devices can be seen in Figure 2-1 (a Host, a Device, a Hub, and a Charger). These are given for reference only and do not limit the possible configurations of products that can be built using this specification.

Figure 2-1 Logical Structure of USB Power Delivery Capable Devices



Claim	Identification

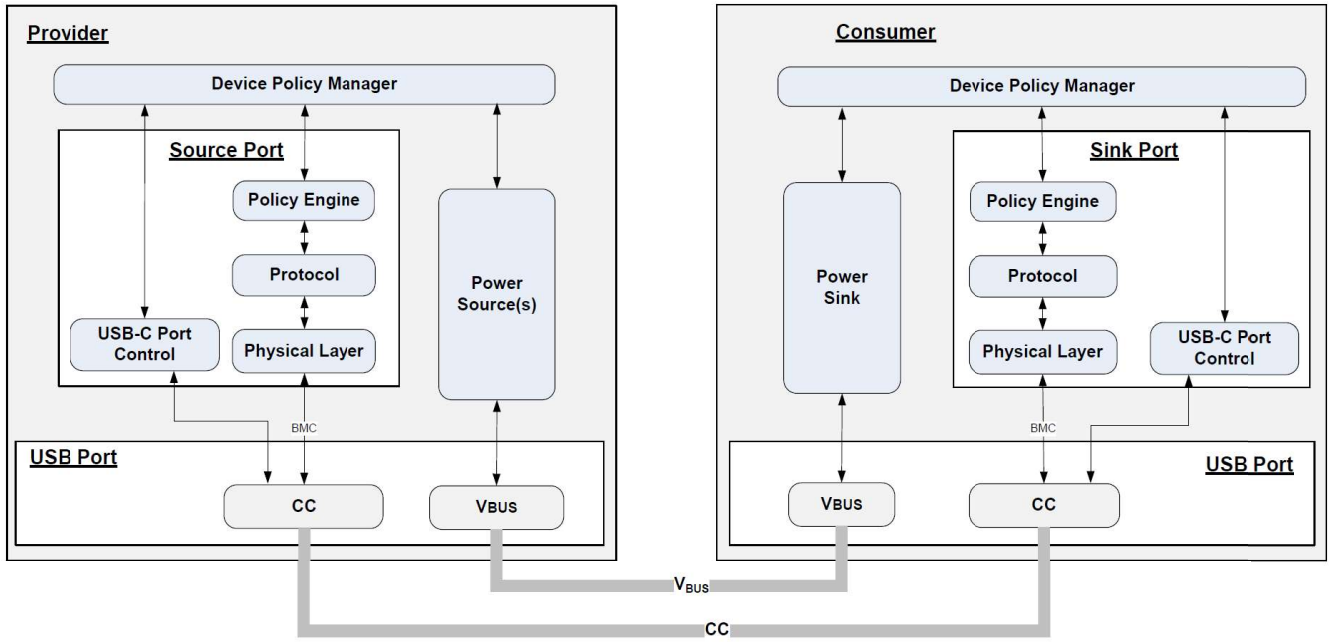
2.7 Architectural Overview

Figure 2-5 shows the logical blocks between two Attached PD ports. In addition to the communication stack described above there are also:

- For a Provider or Dual-Role Power Device: one or more **Sources** providing power to one or more ports.
- For a Consumer or Dual-Role Power Device: A **Sink** consuming power.
- A **USB-C Port Control** module (see Section4.4) that detects cable Attach/Detach as defined in ***[USB Type-C 1.3]***.
- USB Power Delivery uses standard cabling as defined in ***[USB Type-C 1.3]***.

The **Device Policy Manager** talks to the communication stack, Source/Sink and the USB-C Port Control block in order to manage the resources in the Provider or Consumer.

Figure 2-5 High Level Architecture View



Claim	Identification

6.4.1.3 Sink Capabilities Message

A Sink Port ***Shall*** report power levels it is able to operate at in a series of 32-bit Power Data Objects (see Table 6-7). These are returned as part of a ***Sink_Capabilities*** Message in response to a ***Get_Sink_Cap*** Message (see Figure 6-12). This is similar to that used for Source Port capabilities with equivalent Power Data Objects for Fixed, Variable and Battery Supplies as defined in this section. Power Data Objects are used to convey the Sink Port's operational power requirements including Dual-Role Power Ports presently operating as a Source.

Each Power Data Object ***Shall*** describe a specific Sink operational power level, such as a Battery (e.g. 2.8-4.1V) or a fixed power supply (e.g. 12V). The ***Number of Data Objects*** field in the Message Header ***Shall*** define the number of Power Data Objects that follow the Message Header in a Data Message.

All Sinks ***Shall*** minimally offer one Power Data Object with a power level at which the Sink can operate. A Sink ***Shall Not*** offer multiple Power Data Objects of the same type (fixed, variable, Battery) and the same voltage but ***Shall*** instead offer one Power Data Object with the highest available current for that Sink capability and voltage.

All Sinks ***Shall*** include one Power Data Object that reports ***vSafe5V*** even if they require additional power to operate fully. In the case where additional power is required for full operation the Higher Capability bit ***Shall*** be set.

6.4.1.3.1 Sink Fixed Supply Power Data Object

Table 6-14 describes the Sink Fixed Supply (00b) PDO. See Section 7.1.3 for the electrical requirements of the power supply. The Sink ***Shall*** set Voltage to its required voltage and Operational Current to its required operating current. Required operating current is defined as the amount of current a given device needs to be functional. This value could be the maximum current the Sink will ever require or could be sufficient to operate the Sink in one of its modes of operation.

Since all USB Consumers support ***vSafe5V***, the required ***vSafe5V*** Fixed Supply Power Data Object is also used to convey additional information that is returned in bits 29 through 20. All other Fixed Supply Power Data Objects ***Shall*** set bits 29...20 to zero.

For a Sink requiring no power from the Source, the Voltage (B19...10) ***Shall*** be set to 5V and the Operational Current ***Shall*** be set to 0mA.

Claim	Identification

6.4.4.3.1 Discover Identity

The ***Discover Identity*** Command is provided to enable an Initiator to identify its Port Partner and for an Initiator (VCONN Source) to identify the Responder (Cable Plug). The ***Discover Identity*** Command is also used to determine whether a Cable Plug is PD-Capable by looking for a ***GoodCRC*** Message Response.

The ***Discover Identity*** Command ***Shall*** be used to determine whether a given Cable Plug is PD Capable (see Section 8.3.3.18.1 and Section 8.3.3.22.3). In this case a ***Discover Identity*** Command request sent to SOP' ***Shall Not*** cause a Soft Reset if a ***GoodCRC*** Message response is not returned since this can indicate a non-PD Capable cable. Note that a Cable Plug will not be ready for PD Communication until tVCONNStable after VCONN has been applied (see ***[USB Type-C 1.3]***). During Cable Plug discovery, when there is an Explicit Contract, ***Discover Identity*** Commands are sent at a rate defined by the ***DiscoverIdentityTimer*** (see Section 6.6.14) up to a maximum of ***nDiscoverIdentityCount*** times (see Section 6.7.5).

The ***Discover Identity*** Command ACK sent back by the Responder ***Shall*** contain an ID Header VDO, a Cert Stat VDO, a Product VDO and the Product Type VDOs defined by the Product Type as shown in Figure 6-15. This specification defines the following Product Type VDOs:

- Passive Cable VDO (see Section 6.4.4.3.1.4)
- Active Cable VDOs (see Section 6.4.4.3.1.5)
- Alternate Mode Adapter VDO (see Section 6.4.4.3.1.6)
- VCONN Powered USB Device VDO (see Section 6.4.4.3.1.7)

No VDOs other than those defined in this specification ***Shall*** be sent as part of the ***Discover Identity*** Command response. Where there is no Product Type VDO defined for a specific Product Type, no VDOs ***Shall*** be sent as part of the ***Discover Identity*** Command response. Any additional VDOs received by the initiator ***Shall*** be ***Ignored***.

Figure 6-15 Discover Identity Command response

Header No. of Data Objects = 4-7[1]	VDM Header	ID Header VDO	Cert Stat VDO	Product VDO	0..3[2] Product Type VDO(s)

[1] Only Data objects defined in this specification can be sent as part of the ***Discover Identity*** Command.

[2] The following sections define the number and content of the VDOs for each Product Type.

6.4.4.3.1.3 Product Type (UFP)

The Product Type (UFP) field indicates the type of Product when in UFP Data Role, whether a VDO will be returned and if so the type of VDO to be returned. The Product Type indicated in the Product Type (UFP) field ***Shall*** be the closest categorization of the main functionality of the Product in UFP Data Role or "Undefined" when there is no suitable category for the product. For DRD Products this field ***Shall*** always indicate the Product Type when in UFP role regardless of the present Data Role. Table 6-30 defines the Product Type VDOs which ***Shall*** be returned.

Claim	Identification

Table 6-30 Product Types (UFP)

Product Type	Description	Product Type VDO	Reference
Undefined	***Shall*** be used where no other Product Type value is appropriate.	None	
PDUSB Hub	***Shall*** be used when the Product is a PDUSB Hub.	None	
PDUSB Peripheral	***Shall*** be used when the Product is a PDUSB Device other than a PDUSB Hub.	None	
PSD	***Shall*** be used when the Product is a PSD, e.g. power bank.	None	
Alternate Mode Adapter	***Shall*** be used when the Product is a PDUSB Device that supports one or more Alternate Modes.	AMA VDO	Section 6.4.4.3.1.6
VCONN Powered USB Device	***Shall*** be used when the Product is a PDUSB VCONN Powered USB Device.	VPD VDO	Section 6.4.4.3.1.7

6.4.4.3.1.1.4 Product Type (Cable Plug)

The Product Type (Cable Plug) field indicates the type of Product when the Product is a Cable Plug, whether a VDO will be returned and if so the type of VDO to be returned. Table 6-31 defines the Product Type VDOs which ***Shall*** be returned.

Table 6-31 Product Types (Cable Plug)

Product Type	Description	Product Type VDO	Reference
Undefined	***Shall*** be used where no other Product Type value is appropriate.	None	
Active Cable	***Shall*** be used when the Product is a cable that incorporates signal conditioning circuits.	Active Cable VDO	Section 6.4.4.3.1.5
Passive Cable	***Shall*** be used when the Product is a cable that does not incorporate signal conditioning circuits.	Passive Cable VDO	Section 6.4.4.3.1.4

6.4.4.3.1.3 Product VDO

The Product VDO contains identity information relating to the product. The fields in the Product VDO ***Shall*** be as defined in Table 6-34.

Table 6-34 Product VDO

Bit(s)	Description	Reference
B31...16	16-bit unsigned integer. USB Product ID	*[USB 2.0]/[USB 3.2]*
B15...0	16-bit unsigned integer. bcdDevice	*[USB 2.0]/[USB 3.2]*

Claim	Identification

6.5.5 Battery_Capabilities Message

The ***Battery_Capabilities*** Message is sent in response to a ***Get_Battery_Cap*** Message. The ***Battery_Capabilities*** Message contains one Battery Capability Data Block (BCDB) for one of the Batteries its supports as reported by Battery field in the ***Source_Capabilities_Extended*** Message. The returned BCDB ***Shall*** correspond to the Battery requested in the ***Battery Cap Ref*** field contained in the ***Get_Battery_Cap*** Message.

The ***Battery_Capabilities*** Message returns a 9-byte BCDB whose format ***Shall*** be as shown in Figure 6-35 and Table 6-46.

Figure 6-35 Battery_Capabilities Message

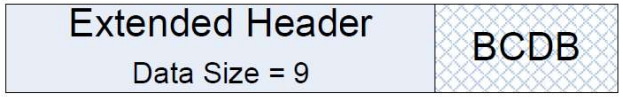


Table 6-50 Battery Capability Data Block (BCDB)

Offset (Byte)	Field	Description
0	VID	Vendor ID (assigned by the USB-IF)
2	PID	Product ID (assigned by the manufacturer)
4	Battery Design Capacity	Battery's design capacity in 0.1 WH Note: 0x0000 = Battery not present 0xFFFF = design capacity unknown
6	Battery Last Full Charge Capacity	Battery's last full charge capacity in 0.1 WH Note: 0x0000 = Battery not present 0xFFFF = last full charge capacity unknown
8	Battery Type	**Bit** / **Description** 0 – Invalid Battery reference 1-7 – ***Reserved***

6.5.5.1 Battery Design Capacity Field

The Battery Design Capacity field ***Shall*** return the Battery's design capacity in tenths of WH. If the Battery is Hot Swappable and is not present, the Battery Design Capacity field ***Shall*** be set to 0. If the Battery is unable to report its Design Capacity, it ***Shall*** return 0xFFFF.

Claim	Identification

6.5.5.3 Battery Type Field

The Battery Type Field is used to report additional information about the Battery's capabilities.

6.5.7 Manufacturer_Info Message

The ***Manufacturer_Info*** Message ***Shall*** be sent in response to a ***Get_Manufacturer_Info*** Message. The ***Manufacturer_Info*** Message contains the USB VID and the Vendor's PID to identify the device or Battery and the device or Battery's manufacturer byte array in a variable length Data Block of up to ***MaxExtendedMsgLegacyLen*** .

The ***Manufacturer_Info*** Message returns a Manufacturer Info Data Block (MIDB) whose format ***Shall*** be as shown in Figure 6-35 and Table 6-46.

Figure 6-37 Manufacturer_Info Message

Table 6-52 Manufacturer Info Data Block (MIDB)

Offset	Field	Description
0	VID	Vendor ID (assigned by the USB-IF)
2	PID	Product ID (assigned by the manufacturer)
4	Manufacturer String	Vendor defined null terminated string of 0…21 characters If the Manufacturer Info Target field or Manufacturer Info Ref field in the ***Get_Manufacturer_Info*** Message is unrecognized return zero bytes.

Claim	Identification

6.5.7.1 **Vendor ID (VID)**

This field ***Shall*** contain the device's or Battery's16-bit vendor ID assigned by the USB.

6.5.7.2 **Product ID (PID)**

This field ***Shall*** contain the device's or Battery's 16-bit product identifier designated by the vendor.

6.5.7.3 **Manufacturer String**

This field ***Shall*** contain the device's or Battery's manufacturer string as defined by the vendor.

If the ***Manufacturer Info Target*** field or ***Manufacturer Info Ref*** field in the ***Get_Manufacturer_Info*** Message is unrecognized the field ***Shall*** return a null terminated ascii text string "Not Supported".

See, e.g., USB 3.0 Promoter Group, *USB Power Delivery Specification* (Rev. 3.0, Ver. 1.2, June 21, 2018) *available at* https://web.archive.org/web/20190212011507/https://www.usb.org/document-library/usb-power-delivery; *see also, e.g.*, *USB Power Delivery – Base Specification*, USB-IF (Oct. 31, 2023), https://www.usb.org/document-library/usb-power-delivery; usb.org, *USB Power Delivery Specification 1.0 – USB.org*, Yumpu (Nov. 24, 2012), https://www.yumpu.com/en/document/view/ 4321520/usb-power-delivery-specification-10-usborg.

USB Power Delivery 1.0, 2.0, 3.0 and 3.1 Standards - Confused yet?

There is no need to be. There are four iterations of the USB PD standard. USB PD 1.0 is a rather basic version providing fixed power profiles, whereas the newer PD 2.0, 3.0 and 3.1 revisions are more dynamic and provide greater flexibility.

USB Power Delivery 1.0

Profile	Voltage	Current	Power	Supported devices
1	5 V	2 A	10 W	smartphones, hard drives, small accessories
2	12 V	1.5 A	18 W	smartphones, tablets, Ultrabooks™, larger accessories
3	12 V	3 A	36 W	future smartphones, notebooks, displays, hubs
4	20 V	3 A	60 W	larger notebooks, hubs, docking stations
5	20 V	5 A	100 W *	workstations, hubs, external graphic cards

Claim	Identification

USB Power Delivery 2.0/3.0

Profile	Voltage	Current	Power	Supported devices
1	5 V	0.1 - 3.0 [A]	10 W	headphones, small accessories
2	9 V	1.67 - 3.0 [A]	15 - 27 W	smartphones, cameras and drones
3	15 V	1.8 - 3.0 [A]	27 - 45 W	tablets, and small laptops
4	20 V	2.25 - 3.0 [A] 3.0 - 5.0 [A] *	45 - 100 W	large laptops and displays

* Requires specially rated **100 W USB-C charging cable**

USB Power Delivery 3.1

The USB PD 3.1 specification divides power into two ranges: Standard Power (SPR), which is the current USB PD3.0 standard with a maximum charging power of 100 W and Extended Power (EPR) with three newly added voltages of 28 V, 36 V, and 48 V. The maximum output current to the three voltages is still 5 A, while the maximum output power can reach 240 W.

Profile	Voltage	Current	Power	Supported devices
5	28 V	3.57 - 5.0 [A] *	140 W	displays, gaming laptops
6	36 V	3.89 - 5.0 [A] *	180 W	displays, gaming laptops
7	48 V	3.75 - 5.0 [A] *	240 W	displays, gaming laptops, desktop PCs

* Requires specially rated 240 W USB-C charging cable

See, e.g., USB-C Power Delivery, Manhattan Products, https://manhattanproducts.eu/pages/usb-c-pd-charging-everything-you-need-to-know.

Claim	Identification
1[a] a charging circuit, and	Nintendo-branded devices include or are accompanied by a charger including a charging circuit.

1.1 Overview

This specification defines how USB Devices can negotiate for more current and/or higher or lower voltages over the USB cable (using the USB Type-C CC wire as the communications channel) than are defined in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 1.3]*** or ***[USBBC 1.2]*** specifications. It allows Devices with greater power requirements than can be met with today's specification to get the power they require to operate from V_{BUS} and negotiate with external power sources (e.g. Wall Warts). In addition, it allows a Source and Sink to swap power roles such that a Device could supply power to the Host. For example, a display could supply power to a notebook to charge its battery.

To facilitate optimum charging, the specification defines two mechanisms a USB Charger can advertise for the Device to use:

1. A list of fixed voltages each with a maximum current. The Device selects a voltage and current from the list. This is the traditional model used by Devices that use internal electronics to manage the charging of their battery including modifying the voltage and current actually supplied to the battery. The side-effect of this model is that the charging circuitry generates heat that may be problematic for small form factor devices.
2. A list of programmable voltage ranges each with a maximum current (PPS). The Device requests a voltage (in 20 mV increments) that is within the advertised range and a maximum current. The USB Charger delivers the requested voltage until the maximum current is reached at which time the USB charger reduces its output voltage so as not to supply more than the requested maximum current. During the high current portion of the charge cycle, the USB Charger can be directly connected (through an appropriate safety device) to the battery. This model is used by Devices that want to minimize the thermal impact of their internal charging circuitry.

1.2 Purpose

The USB Power Delivery specification defines a power delivery system covering all elements of a USB system including: Hosts, Devices, Hubs, Chargers and cable assemblies. This specification describes the architecture, protocols, power supply behavior, connectors and cabling necessary for managing power delivery over USB at up to 100W. This specification is intended to be fully compatible and extend the existing USB infrastructure. It is intended that this specification will allow system OEMs, power supply and peripheral developers adequate flexibility for product versatility and market differentiation without losing backwards compatibility.

USB Power Delivery is designed to operate independently of the existing USB bus defined mechanisms used to negotiate power which are:

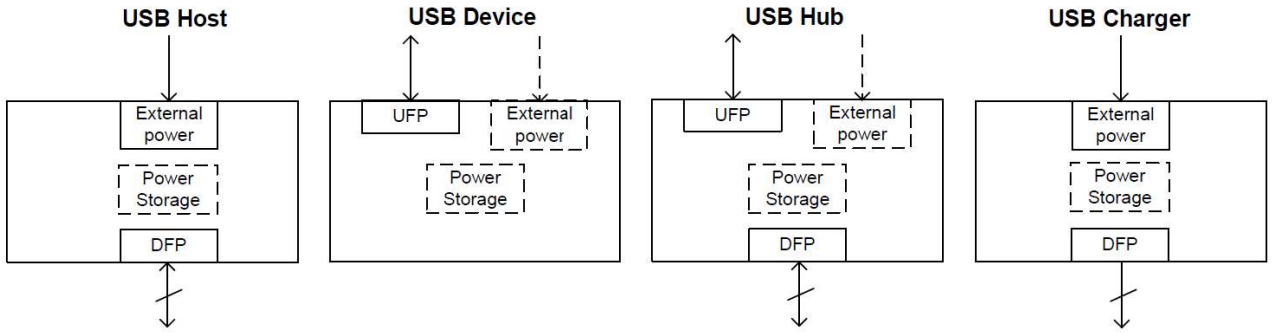
- ***[USB 2.0]***, ***[USB 3.2]*** in band requests for high power interfaces.
- ***[USBBC 1.2]*** mechanisms for supplying higher power (not mandated by this specification).
- ***[USB Type-C 1.3]*** mechanisms for supplying higher power

Claim	Identification

2.4 USB Power Delivery Capable Devices

Some examples of USB Power Delivery capable devices can be seen in Figure 2-1 (a Host, a Device, a Hub, and a Charger). These are given for reference only and do not limit the possible configurations of products that can be built using this specification.

Figure 2-1 Logical Structure of USB Power Delivery Capable Devices

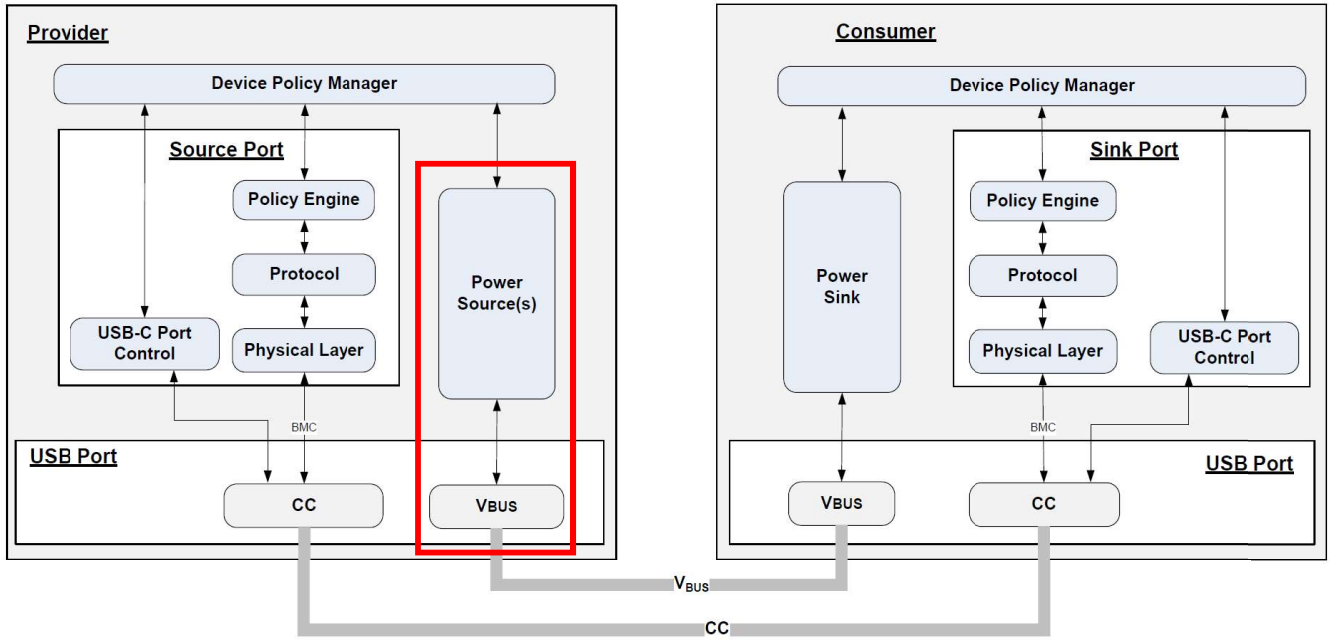


2.7 Architectural Overview

Figure 2-5 shows the logical blocks between two Attached PD ports. In addition to the communication stack described above there are also:

- For a Provider or Dual-Role Power Device: one or more **Sources** providing power to one or more ports.
- For a Consumer or Dual-Role Power Device: A **Sink** consuming power.
- A **USB-C Port Control** module (see Section4.4) that detects cable Attach/Detach as defined in ***[USB Type-C 1.3]***.
- USB Power Delivery uses standard cabling as defined in ***[USB Type-C 1.3]***.

The **Device Policy Manager** talks to the communication stack, Source/Sink and the USB-C Port Control block in order to manage the resources in the Provider or Consumer.

Claim	Identification
	Figure 2-5 High Level Architecture View  *See, e.g.*, USB 3.0 Promoter Group, USB Power Delivery Specification (Rev. 3.0, Ver. 1.2, June 21, 2018) *available at* https://web.archive.org/web/20190212011507/https://www.usb.org/document-library/usb-power-delivery; *see also, e.g.*, *USB Power Delivery – Base Specification*, USB-IF (Oct. 31, 2023), https://www.usb.org/document-library/usb-power-delivery; usb.org, *USB Power Delivery Specification 1.0 – USB.org*, Yumpu (Nov. 24, 2012), https://www.yumpu.com/en/document/view/ 4321520/usb-power-delivery-specification-10-usborg.

Claim	Identification
1[b] a controller coupled to said charging circuit and configured to cause said portable wireless communications device to identify its corresponding portable device type and its corresponding rechargeable battery type, and	Nintendo-branded devices include or are accompanied by a charger including a controller coupled to said charging circuit and configured to cause said portable wireless communications device to identify its corresponding portable device type and its corresponding rechargeable battery type.

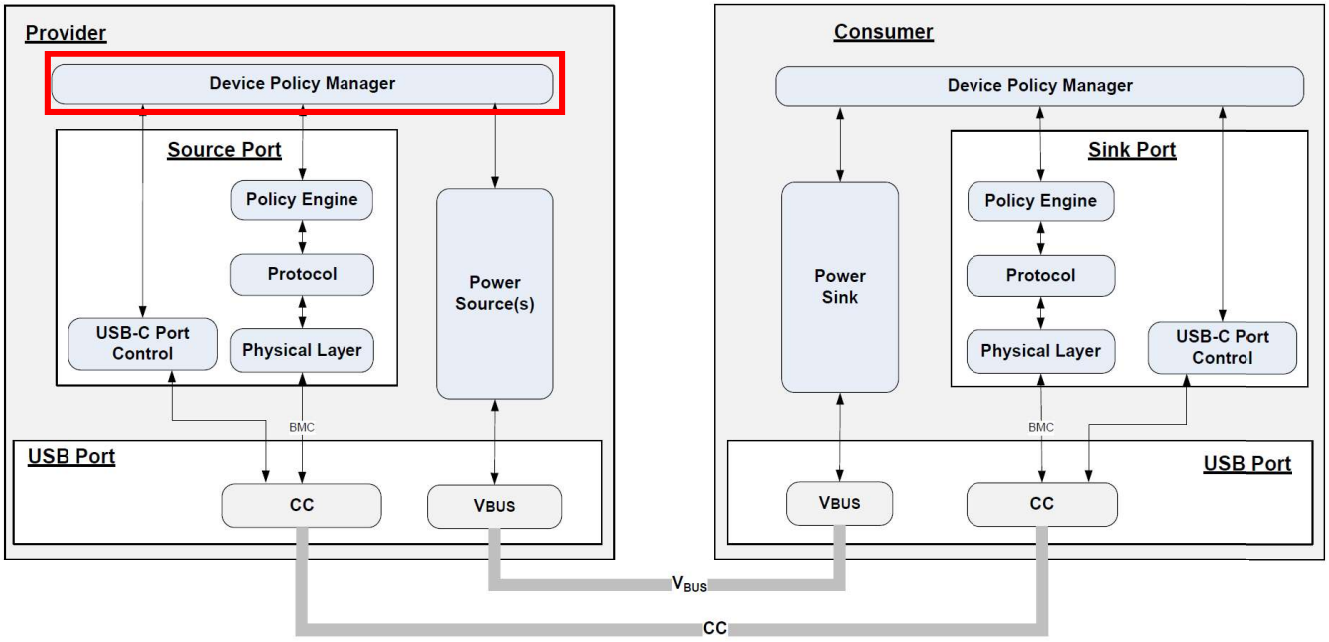
2.7 Architectural Overview

Figure 2-5 shows the logical blocks between two Attached PD ports. In addition to the communication stack described above there are also:

- For a Provider or Dual-Role Power Device: one or more **Sources** providing power to one or more ports.
- For a Consumer or Dual-Role Power Device: A **Sink** consuming power.
- A **USB-C Port Control** module (see Section4.4) that detects cable Attach/Detach as defined in ***[USB Type-C 1.3]***.
- USB Power Delivery uses standard cabling as defined in ***[USB Type-C 1.3]***.

The **Device Policy Manager** talks to the communication stack, Source/Sink and the USB-C Port Control block in order to manage the resources in the Provider or Consumer.

Figure 2-5 High Level Architecture View



Claim	Identification
	8.2 Device Policy Manager The Device Policy Manager is responsible for managing the power used by one or more USB Power Delivery ports. In order to have sufficient knowledge to complete this task it needs relevant information about the device it resides in. Firstly, it has a priori knowledge of the device including the capabilities of the power supply and the receptacles on each Port since these will for example have specific current ratings. It also has to know information from the USB-C Port Control module regarding cable insertion, type and rating of cable etc. It also has to have information from the power supply about changes in its capabilities as well as being able to request power supply changes. With all of this information the Device Policy Manager is able to provide up to date information regarding the capabilities available to a specific Port and to manage the power resources within the device. When working out the capabilities for a given Source Port the Device Policy Manager will take into account firstly the current rating of the Port's receptacle and whether the inserted cable is PD or non-PD rated and if so what is the capability of the plug. This will set an upper bound for the capabilities which might be offered. After this the Device Policy Manager will consider the available power supply resources since this will bound which voltages and currents might be offered. Finally, the Device Policy Manager will consider what power is currently allocated to other ports, which power is in the Power Reserve and any other amendments to Policy from the System Policy Manager. The Device Policy Manager will offer a set of capabilities within the bounds detailed above. When selecting a capability for a given Sink Port the Device Policy Manager will look at the capabilities offered by the Source. This will set an upper bound for the capabilities which might be requested. The Device Policy Manager will also consider which capabilities are required by the Sink in order to operate. If an appropriate match for Voltage and Current can be found within the limits of the receptacle and cable then this will be requested from the Source. If an appropriate match cannot be found then a request for an offered voltage and current will be made, along with an indication of a capability mismatch. **8.2.1 Capabilities** The Device Policy Manager in a Provider ***Shall*** know the power supplies available in the device and their capabilities. In addition, it ***Shall*** be aware of any other PD Sources of power such as batteries and AC inputs. The available power sources and existing demands on the device ***Shall*** be taken into account when presenting capabilities to a Sink. The Device Policy Manager in a Consumer ***Shall*** know the requirements of the Sink and use this to evaluate the capabilities offered by a Source. It ***Shall*** be aware of its own power sources e.g. Batteries or AC supplies where these have a bearing on its operation as a Sink. The Device Policy Manager in a Dual-Role Power Device ***Shall*** combine the above capabilities and ***Shall*** also be able to present the dual-role nature of the device to an Attached PD Capable device.

Claim	Identification

8.2.3 Control of Source/Sink

The Device Policy Manager for a Provider ***Shall*** manage the power supply for each PD Source Port and ***Shall*** know at any given time what the negotiated power is. It ***Shall*** request transitions of the supply and inform the Policy Engine whenever a transition completes.

The Device Policy Manager for a Consumer ***Shall*** manage the Sink for each PD Sink Port and ***Shall*** know at any given time what the negotiated power is.

The Device Policy Manager for a Dual-Role Power Device ***Shall*** manage the transition between Source/Sink roles for each PD Dual-Role Power Port and ***Shall*** know at any given time what operational role the Port is in.

8.3.2.2 Power Negotiation

8.3.2.2.1 Explicit Contract Negotiation

Figure 8-5 illustrates an example of a successful Message flow while negotiating an Explicit Contract. The negotiation goes through 5 distinct phases:

- The Source sends out its power capabilities in a ***Source_Capabilities*** Message.
- The Sink evaluates these capabilities and in the request phase selects one power level by sending a ***Request*** Message.
- The Source evaluates the request and accepts the request with an ***Accept*** Message.
- The Source transitions to the new power level and then informs the Sink by sending a ***PS_RDY*** Message.
- The Sink starts using the new power level.
- For PPS operation:
  - the Source starts its keep alive timer
  - the Sink starts its request timer to send periodic ***Request*** Messages

6.4.2 Request Message

A ***Request*** Message ***Shall*** be sent by a Sink to request power, typically during the request phase of a power negotiation. The Request Data Object ***Shall*** be returned by the Sink making a request for power. It ***Shall*** be sent in response to the most recent ***Source_Capabilities*** Message (see Section 8.3.2.2). A ***Request*** Message ***Shall*** return one and only one Sink Request Data Object that ***Shall*** identify the Power Data Object being requested.

The ***Request*** Message includes the requested power level. For example, if the ***Source_Capabilities*** Message includes a Fixed Supply PDO that offers 12V @ 1.5A and if the Sink only wants 12V @ 0.5A, it will set the Operating Current field to 50 (i.e. 10mA * 50 = 0.5A). The ***Request*** Message requests the highest current the Sink will ever require in the Maximum Operating Current Field (in this example it would be 100 (100 * 10mA = 1.0A)).

Claim	Identification

6.4.2.3 Capability Mismatch

A Capability Mismatch occurs when the Sink cannot satisfy its power requirements from the capabilities offered by the Source. In this case the Sink ***Shall*** make a ***Valid*** request from the offered capabilities and ***Shall*** set the Capability Mismatch bit (see Section 8.2.5.2).

When a Sink returns a Request Data Object in response to advertised capabilities with this bit set, it indicates that the Sink wants power that the Source cannot provide. This can be due to either a voltage that is not available or the amount of available current. At this point the Source can use the information in the ***Request*** Message combined with the contents of the ***Sink_Capabilities*** Message to ascertain the Voltage and Current required by the Sink for full operation.

In this context a ***Valid Request*** Message means the following:

- The Object position field ***Shall*** contain a reference to an object in the last received ***Source_Capabilities*** Message.
- The Operating Current/Power field ***Shall*** contain a value which is less than or equal to the maximum current/power offered in the ***Source_Capabilities*** Message.
- If the GiveBack flag is set to zero i.e. there is a Maximum Operating Current/Power field:
  - If the Capability Mismatch bit is set to one:
    - The Maximum Operating Current/Power field ***May*** contain a value larger than the maximum current/power offered in the ***Source_Capabilities*** Message's PDO as referenced by the Object position field. This enables the Sink to indicate that it requires more current/power than is being offered. If the Sink requires a different voltage this will be indicated by its ***Sink_Capabilities*** Message.
  - Else if the Capability Mismatch bit is set to zero:
    - The Maximum Operating Current/Power field ***Shall*** contain a value less than or equal to the maximum current/power offered in the ***Source_Capabilities*** Message's PDO as referenced by the Object position field.
- Else if the GiveBack flag is set to one i.e. there is a Minimum Operating Current/Power field:
  - The Minimum Operating Current/Power field ***Shall*** contain a value less than the Operating Current/Power field.

Claim	Identification

6.4.1.3 Sink Capabilities Message

A Sink Port ***Shall*** report power levels it is able to operate at in a series of 32-bit Power Data Objects (see Table 6-7). These are returned as part of a ***Sink_Capabilities*** Message in response to a ***Get_Sink_Cap*** Message (see Figure 6-12). This is similar to that used for Source Port capabilities with equivalent Power Data Objects for Fixed, Variable and Battery Supplies as defined in this section. Power Data Objects are used to convey the Sink Port's operational power requirements including Dual-Role Power Ports presently operating as a Source.

Each Power Data Object ***Shall*** describe a specific Sink operational power level, such as a Battery (e.g. 2.8-4.1V) or a fixed power supply (e.g. 12V). The ***Number of Data Objects*** field in the Message Header ***Shall*** define the number of Power Data Objects that follow the Message Header in a Data Message.

All Sinks ***Shall*** minimally offer one Power Data Object with a power level at which the Sink can operate. A Sink ***Shall Not*** offer multiple Power Data Objects of the same type (fixed, variable, Battery) and the same voltage but ***Shall*** instead offer one Power Data Object with the highest available current for that Sink capability and voltage.

All Sinks ***Shall*** include one Power Data Object that reports ***vSafe5V*** even if they require additional power to operate fully. In the case where additional power is required for full operation the Higher Capability bit ***Shall*** be set.

6.4.1.3.1 Sink Fixed Supply Power Data Object

Table 6-14 describes the Sink Fixed Supply (00b) PDO. See Section 7.1.3 for the electrical requirements of the power supply. The Sink ***Shall*** set Voltage to its required voltage and Operational Current to its required operating current. Required operating current is defined as the amount of current a given device needs to be functional. This value could be the maximum current the Sink will ever require or could be sufficient to operate the Sink in one of its modes of operation.

Since all USB Consumers support ***vSafe5V***, the required ***vSafe5V*** Fixed Supply Power Data Object is also used to convey additional information that is returned in bits 29 through 20. All other Fixed Supply Power Data Objects ***Shall*** set bits 29...20 to zero.

For a Sink requiring no power from the Source, the Voltage (B19...10) ***Shall*** be set to 5V and the Operational Current ***Shall*** be set to 0mA.

Claim	Identification

Table 6-14 Fixed Supply PDO - Sink

Bit(s)	Description
B31...30	Fixed supply
B29	Dual-Role Power
B28	Higher Capability
B27	Unconstrained Power
B26	USB Communications Capable
B25	Dual-Role Data
B24...23	Fast Role Swap required USB Type-C Current (see also ***[USB Type-C 1.3]***):
B22...20	***Reserved – Shall*** be set to zero.
B19...10	Voltage in 50mV units
B9...0	Operational Current in 10mA units

Value	Description
00b	Fast Swap not supported (default)
01b	Default USB Power
10b	1.5A @ 5V
11b	3.0A @ 5V

8.2.4 Cable Detection

8.2.4.1 Device Policy Manager in a Provider

The Device Policy Manager in the Provider ***Shall*** control the USB-C Port Control module and ***Shall*** be able to use the USB-C Port Control module to determine the Attachment status.

Note: that it might be necessary for the Device Policy Manager to also initiate additional discovery using the ***Discover Identity*** Command in order to determine the full capabilities of the cabling (see Section 6.4.4.2).

Claim	Identification

6.4.4.3.1 Discover Identity

The ***Discover Identity*** Command is provided to enable an Initiator to identify its Port Partner and for an Initiator (VCONN Source) to identify the Responder (Cable Plug). The ***Discover Identity*** Command is also used to determine whether a Cable Plug is PD-Capable by looking for a ***GoodCRC*** Message Response.

The ***Discover Identity*** Command ***Shall*** be used to determine whether a given Cable Plug is PD Capable (see Section 8.3.3.18.1 and Section 8.3.3.22.3). In this case a ***Discover Identity*** Command request sent to SOP' ***Shall Not*** cause a Soft Reset if a ***GoodCRC*** Message response is not returned since this can indicate a non-PD Capable cable. Note that a Cable Plug will not be ready for PD Communication until tVCONNStable after VCONN has been applied (see ***[USB Type-C 1.3]***). During Cable Plug discovery, when there is an Explicit Contract, ***Discover Identity*** Commands are sent at a rate defined by the ***DiscoverIdentityTimer*** (see Section 6.6.14) up to a maximum of ***nDiscoverIdentityCount*** times (see Section 6.7.5).

The ***Discover Identity*** Command ACK sent back by the Responder ***Shall*** contain an ID Header VDO, a Cert Stat VDO, a Product VDO and the Product Type VDOs defined by the Product Type as shown in Figure 6-15. This specification defines the following Product Type VDOs:

- Passive Cable VDO (see Section 6.4.4.3.1.4)
- Active Cable VDOs (see Section 6.4.4.3.1.5)
- Alternate Mode Adapter VDO (see Section 6.4.4.3.1.6)
- VCONN Powered USB Device VDO (see Section 6.4.4.3.1.7)

No VDOs other than those defined in this specification ***Shall*** be sent as part of the ***Discover Identity*** Command response. Where there is no Product Type VDO defined for a specific Product Type, no VDOs ***Shall*** be sent as part of the ***Discover Identity*** Command response. Any additional VDOs received by the initiator ***Shall*** be ***Ignored***.

Figure 6-15 Discover Identity Command response

Header No. of Data Objects = 4-7[1]	VDM Header	ID Header VDO	Cert Stat VDO	Product VDO	0..3[2] Product Type VDO(s)

[1] Only Data objects defined in this specification can be sent as part of the ***Discover Identity*** Command.

[2] The following sections define the number and content of the VDOs for each Product Type.

Claim	Identification

6.4.4.3.1.1.3 Product Type (UFP)

The Product Type (UFP) field indicates the type of Product when in UFP Data Role, whether a VDO will be returned and if so the type of VDO to be returned. The Product Type indicated in the Product Type (UFP) field ***Shall*** be the closest categorization of the main functionality of the Product in UFP Data Role or "Undefined" when there is no suitable category for the product. For DRD Products this field ***Shall*** always indicate the Product Type when in UFP role regardless of the present Data Role. Table 6-30 defines the Product Type VDOs which ***Shall*** be returned.

Table 6-30 Product Types (UFP)

Product Type	Description	Product Type VDO	Reference
Undefined	***Shall*** be used where no other Product Type value is appropriate.	None	
PDUSB Hub	***Shall*** be used when the Product is a PDUSB Hub.	None	
PDUSB Peripheral	***Shall*** be used when the Product is a PDUSB Device other than a PDUSB Hub.	None	
PSD	***Shall*** be used when the Product is a PSD, e.g. power bank.	None	
Alternate Mode Adapter	***Shall*** be used when the Product is a PDUSB Device that supports one or more Alternate Modes.	AMA VDO	Section 6.4.4.3.1.6
VCONN Powered USB Device	***Shall*** be used when the Product is a PDUSB VCONN Powered USB Device.	VPD VDO	Section 6.4.4.3.1.7

6.4.4.3.1.1.4 Product Type (Cable Plug)

The Product Type (Cable Plug) field indicates the type of Product when the Product is a Cable Plug, whether a VDO will be returned and if so the type of VDO to be returned. Table 6-31 defines the Product Type VDOs which ***Shall*** be returned.

Table 6-31 Product Types (Cable Plug)

Product Type	Description	Product Type VDO	Reference
Undefined	***Shall*** be used where no other Product Type value is appropriate.	None	
Active Cable	***Shall*** be used when the Product is a cable that incorporates signal conditioning circuits.	Active Cable VDO	Section 6.4.4.3.1.5
Passive Cable	***Shall*** be used when the Product is a cable that does not incorporate signal conditioning circuits.	Passive Cable VDO	Section 6.4.4.3.1.4

Claim	Identification

6.4.4.3.1.3 Product VDO

The Product VDO contains identity information relating to the product. The fields in the Product VDO ***Shall*** be as defined in Table 6-34.

Table 6-34 Product VDO

Bit(s)	Description	Reference
B31...16	16-bit unsigned integer. USB Product ID	*[USB 2.0]/[USB 3.2]*
B15...0	16-bit unsigned integer. bcdDevice	*[USB 2.0]/[USB 3.2]*

6.5.5 Battery_Capabilities Message

The ***Battery_Capabilities*** Message is sent in response to a ***Get_Battery_Cap*** Message. The ***Battery_Capabilities*** Message contains one Battery Capability Data Block (BCDB) for one of the Batteries its supports as reported by Battery field in the ***Source_Capabilities_Extended*** Message. The returned BCDB ***Shall*** correspond to the Battery requested in the ***Battery Cap Ref*** field contained in the ***Get_Battery_Cap*** Message.

The ***Battery_Capabilities*** Message returns a 9-byte BCDB whose format ***Shall*** be as shown in Figure 6-35 and Table 6-46.

Figure 6-35 Battery_Capabilities Message

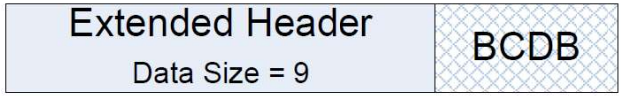


Table 6-50 Battery Capability Data Block (BCDB)

Offset (Byte)	Field	Description
0	VID	Vendor ID (assigned by the USB-IF)
2	PID	Product ID (assigned by the manufacturer)
4	Battery Design Capacity	Battery's design capacity in 0.1 WH Note: 0x0000 = Battery not present 0xFFFF = design capacity unknown
6	Battery Last Full Charge Capacity	Battery's last full charge capacity in 0.1 WH Note: 0x0000 = Battery not present 0xFFFF = last full charge capacity unknown

Claim	Identification

8	Battery Type	

Bit	Description
0	Invalid Battery reference
1-7	***Reserved***

6.5.5.1 Battery Design Capacity Field

The Battery Design Capacity field ***Shall*** return the Battery's design capacity in tenths of WH. If the Battery is Hot Swappable and is not present, the Battery Design Capacity field ***Shall*** be set to 0. If the Battery is unable to report its Design Capacity, it ***Shall*** return 0xFFFF.

6.5.5.3 Battery Type Field

The Battery Type Field is used to report additional information about the Battery's capabilities.

6.5.7 Manufacturer_Info Message

The ***Manufacturer_Info*** Message ***Shall*** be sent in response to a ***Get_Manufacturer_Info*** Message. The ***Manufacturer_Info*** Message contains the USB VID and the Vendor's PID to identify the device or Battery and the device or Battery's manufacturer byte array in a variable length Data Block of up to ***MaxExtendedMsgLegacyLen*** .

The ***Manufacturer_Info*** Message returns a Manufacturer Info Data Block (MIDB) whose format ***Shall*** be as shown in Figure 6-35 and Table 6-46.

Figure 6-37 Manufacturer_Info Message

Table 6-52 Manufacturer Info Data Block (MIDB)

Offset	Field	Description
0	VID	Vendor ID (assigned by the USB-IF)
2	PID	Product ID (assigned by the manufacturer)
4	Manufacturer String	Vendor defined null terminated string of 0...21 characters If the Manufacturer Info Target field or Manufacturer Info Ref field in the ***Get_Manufacturer_Info*** Message is unrecognized return zero bytes.

Claim	Identification
	6.5.7.1 **Vendor ID (VID)** This field ***Shall*** contain the device's or Battery's16-bit vendor ID assigned by the USB. 6.5.7.2 **Product ID (PID)** This field ***Shall*** contain the device's or Battery's 16-bit product identifier designated by the vendor. 6.5.7.3 **Manufacturer String** This field ***Shall*** contain the device's or Battery's manufacturer string as defined by the vendor. If the ***Manufacturer Info Target*** field or ***Manufacturer Info Ref*** field in the ***Get_Manufacturer_Info*** Message is unrecognized the field ***Shall*** return a null terminated ascii text string "Not Supported". *See, e.g.*, USB 3.0 Promoter Group, *USB Power Delivery Specification* (Rev. 3.0, Ver. 1.2, June 21, 2018) *available at* https://web.archive.org/web/20190212011507/https://www.usb.org/document-library/usb-power-delivery; *see also, e.g.*, *USB Power Delivery – Base Specification*, USB-IF (Oct. 31, 2023), https://www.usb.org/document-library/usb-power-delivery; usb.org, *USB Power Delivery Specification 1.0 – USB.org*, Yumpu (Nov. 24, 2012), https://www.yumpu.com/en/document/view/ 4321520/usb-power-delivery-specification-10-usborg.
1[c] to cause said charging circuit to charge the rechargeable battery based on the respective charging rate thereof.	Nintendo-branded devices include or are accompanied by a charger including a controller coupled to said charging circuit and configured to cause said charging circuit to charge the rechargeable battery based on the respective charging rate thereof. 8.3.2.2 **Power Negotiation** 8.3.2.2.1 Explicit Contract Negotiation Figure 8-5 illustrates an example of a successful Message flow while negotiating an Explicit Contract. The negotiation goes through 5 distinct phases: • The Source sends out its power capabilities in a ***Source_Capabilities*** Message. • The Sink evaluates these capabilities and in the request phase selects one power level by sending a ***Request*** Message. • The Source evaluates the request and accepts the request with an ***Accept*** Message. • The Source transitions to the new power level and then informs the Sink by sending a ***PS_RDY*** Message. • The Sink starts using the new power level. • For PPS operation: ○ the Source starts its keep alive timer ○ the Sink starts its request timer to send periodic ***Request*** Messages

Claim	Identification

6.4.1.3 Sink Capabilities Message

A Sink Port ***Shall*** report power levels it is able to operate at in a series of 32-bit Power Data Objects (see Table 6-7). These are returned as part of a ***Sink_Capabilities*** Message in response to a ***Get_Sink_Cap*** Message (see Figure 6-12). This is similar to that used for Source Port capabilities with equivalent Power Data Objects for Fixed, Variable and Battery Supplies as defined in this section. Power Data Objects are used to convey the Sink Port's operational power requirements including Dual-Role Power Ports presently operating as a Source.

Each Power Data Object ***Shall*** describe a specific Sink operational power level, such as a Battery (e.g. 2.8-4.1V) or a fixed power supply (e.g. 12V). The ***Number of Data Objects*** field in the Message Header ***Shall*** define the number of Power Data Objects that follow the Message Header in a Data Message.

All Sinks ***Shall*** minimally offer one Power Data Object with a power level at which the Sink can operate. A Sink ***Shall Not*** offer multiple Power Data Objects of the same type (fixed, variable, Battery) and the same voltage but ***Shall*** instead offer one Power Data Object with the highest available current for that Sink capability and voltage.

All Sinks ***Shall*** include one Power Data Object that reports ***vSafe5V*** even if they require additional power to operate fully. In the case where additional power is required for full operation the Higher Capability bit ***Shall*** be set.

6.4.1.3.1 Sink Fixed Supply Power Data Object

Table 6-14 describes the Sink Fixed Supply (00b) PDO. See Section 7.1.3 for the electrical requirements of the power supply. The Sink ***Shall*** set Voltage to its required voltage and Operational Current to its required operating current. Required operating current is defined as the amount of current a given device needs to be functional. This value could be the maximum current the Sink will ever require or could be sufficient to operate the Sink in one of its modes of operation.

Since all USB Consumers support ***vSafe5V***, the required ***vSafe5V*** Fixed Supply Power Data Object is also used to convey additional information that is returned in bits 29 through 20. All other Fixed Supply Power Data Objects ***Shall*** set bits 29...20 to zero.

For a Sink requiring no power from the Source, the Voltage (B19...10) ***Shall*** be set to 5V and the Operational Current ***Shall*** be set to 0mA.

Claim	Identification

Table 6-14 Fixed Supply PDO - Sink

Bit(s)	Description
B31...30	Fixed supply
B29	Dual-Role Power
B28	Higher Capability
B27	Unconstrained Power
B26	USB Communications Capable
B25	Dual-Role Data
B24...23	Fast Role Swap required USB Type-C Current (see also ***[USB Type-C 1.3]***): **Value** / **Description** 00b – Fast Swap not supported (default) 01b – Default USB Power 10b – 1.5A @ 5V 11b – 3.0A @ 5V
B22...20	***Reserved – Shall*** be set to zero.
B19...10	Voltage in 50mV units
B9...0	Operational Current in 10mA units

6.4.2 Request Message

A ***Request*** Message ***Shall*** be sent by a Sink to request power, typically during the request phase of a power negotiation. The Request Data Object ***Shall*** be returned by the Sink making a request for power. It ***Shall*** be sent in response to the most recent ***Source_Capabilities*** Message (see Section 8.3.2.2). A ***Request*** Message ***Shall*** return one and only one Sink Request Data Object that ***Shall*** identify the Power Data Object being requested.

The ***Request*** Message includes the requested power level. For example, if the ***Source_Capabilities*** Message includes a Fixed Supply PDO that offers 12V @ 1.5A and if the Sink only wants 12V @ 0.5A, it will set the Operating Current field to 50 (i.e. 10mA * 50 = 0.5A). The ***Request*** Message requests the highest current the Sink will ever require in the Maximum Operating Current Field (in this example it would be 100 (100 * 10mA = 1.0A)).

Claim	Identification

	6.4.2.3 Capability Mismatch
	
	A Capability Mismatch occurs when the Sink cannot satisfy its power requirements from the capabilities offered by the Source. In this case the Sink ***Shall*** make a ***Valid*** request from the offered capabilities and ***Shall*** set the Capability Mismatch bit (see Section 8.2.5.2).
	
	When a Sink returns a Request Data Object in response to advertised capabilities with this bit set, it indicates that the Sink wants power that the Source cannot provide. This can be due to either a voltage that is not available or the amount of available current. At this point the Source can use the information in the ***Request*** Message combined with the contents of the ***Sink_Capabilities*** Message to ascertain the Voltage and Current required by the Sink for full operation.
	
	In this context a ***Valid Request*** Message means the following:
	
	• The Object position field ***Shall*** contain a reference to an object in the last received ***Source_Capabilities*** Message.
	• The Operating Current/Power field ***Shall*** contain a value which is less than or equal to the maximum current/power offered in the ***Source_Capabilities*** Message.
	• If the GiveBack flag is set to zero i.e. there is a Maximum Operating Current/Power field:
	  ○ If the Capability Mismatch bit is set to one:
	  ▪ The Maximum Operating Current/Power field ***May*** contain a value larger than the maximum current/power offered in the ***Source_Capabilities*** Message's PDO as referenced by the Object position field. This enables the Sink to indicate that it requires more current/power than is being offered. If the Sink requires a different voltage this will be indicated by its ***Sink_Capabilities*** Message.
	  ○ Else if the Capability Mismatch bit is set to zero:
	  ▪ The Maximum Operating Current/Power field ***Shall*** contain a value less than or equal to the maximum current/power offered in the ***Source_Capabilities*** Message's PDO as referenced by the Object position field.
	• Else if the GiveBack flag is set to one i.e. there is a Minimum Operating Current/Power field:
	  ○ The Minimum Operating Current/Power field ***Shall*** contain a value less than the Operating Current/Power field.

Claim	Identification

10.2.2 Normative Voltages and Currents

The voltages and currents a Source with a PDP Rating of x Watts ***Shall*** support are as defined in Table 10-2.

Table 10-2 Normative Voltages and Minimum Currents

PDP Rating (W)	Current at 5V (A)	Current at 9V (A)	Current at 15V (A)	Current at 20V (A)
0.5 ≤ x ≤ 15	x ÷ 5			
15 < x ≤ 27	3	x ÷ 9		
27 < x ≤ 45	3	3	x ÷ 15	
45 < x ≤ 60	3	3	3	x ÷ 20
60 < x ≤ 100	3	3	3	x ÷ 20[1]

[1] Requires a 5A cable.

Figure 10-1 illustrates the minimum current that a Source ***Shall*** support at each voltage for a given PDP Rating. Note: Not illustrated are that currents higher than 3A are allowed to be offered up to a limit of 5A given that a 5A cable is detected by the Source and the voltage times current remains within the Source PDP Rating.

Figure 10-1 Source Power Rule Illustration

Claim	Identification

10.2.3.2 **Optional Normative Programmable Power Supply**

The voltages and currents a Programmable Power Supply with a PDP Rating of x Watts ***Shall*** support are as defined in Table 10-7.

When ***Optional*** Programmable Power Supply APDOs are offered, the following requirements ***Shall*** apply:

- A Source that advertises ***Optional*** Programmable Power Supply APDOs ***Shall*** advertise the PDOs and APDOs shown in Table 10-7.
- A Source ***Shall*** advertise ***Optional*** Programmable Power Supply APDOs with Maximum Voltage and Minimum Voltages for nominal voltage as defined in Table 10-8.
- A Source that advertises Programmable Power Supply APDOs other than the ones listed in Table 10-8 ***Shall*** advertise additional APDO's with a maximum current of RoundDown (x/Max Voltage) to the nearest 50mA.
- In no case ***Shall*** a Source advertise a current that exceeds the attached cable's current rating.

Table 10-7 Programmable Power Supply PDOs and APDOs based on the PDP

PDP Rating (W)	5V fixed	9V fixed	15V fixed	20V fixed	5V Prog	9V Prog	15V Prog	20V Prog
x < 15W	PDP/5[4]	-	-	-	PDP/5[1]	-	-	-
15W	3A	-	-	-	3A	-	-	-
15 < x < 27W	3A[3]	PDP/9[4]	-	-	3A[2]	PDP/9[1]	-	-
27W	3A[3]	3A	-	-	-	3A	-	-
27 < x < 45W	3A[3]	3A[3]	PDP/15[4]	-	-	3A[2]	PDP/15[1]	-
45W	3A[3]	3A[3]	3A	-	-	-	3A	-
45 < x < 60W	3A[3]	3A[3]	3A[3]	PDP/20[4]	-	-	3A[2]	PDP/20[1]
60W	3A[3]	3A[3]	3A[3]	3A[3]	-	-	-	3A
60 < x < 100W	3A[3]	3A[3]	3A[3]	PDP/20[4]	-	-	-	PDP/20[2]
100W	3A[3]	3A[3]	3A[3]	5A	-	-	-	5A

Notes:
1. The PPS APDOs Maximum Current field ***Shall*** advertise RoundDown (PDP/Prog Voltage) to the nearest 50mA.
2. The PPS APDOs Maximum Current field ***Shall*** advertise at least 3A, but ***May*** advertise up to RoundDown(PDP/Prog voltage) to the nearest 50mA.
3. The Fixed PDOs Maximum Current field ***Shall*** advertise at least 3A, but ***May*** advertise up to RoundUp (PDP/voltage.) to the nearest 10mA.
4. The Fixed PDOs Maximum Current field ***Shall*** advertise either RoundDown (PDP/Voltage) or RoundUp (PDP/Voltage) to the nearest 10mA.

See, e.g., USB 3.0 Promoter Group, USB Power Delivery Specification (Rev. 3.0, Ver. 1.2, June 21, 2018) *available at* https://web.archive.org/web/20190212011507/https://www.usb.org/document-library/usb-power-delivery; *see also, e.g.*,

Claim	Identification
	USB Power Delivery – Base Specification, USB-IF (Oct. 31, 2023), https://www.usb.org/document-library/usb-power-delivery; usb.org, *USB Power Delivery Specification 1.0 – USB.org*, Yumpu (Nov. 24, 2012), https://www.yumpu.com/en/document/view/ 4321520/usb-power-delivery-specification-10-usborg.

USB Power Delivery 1.0, 2.0, 3.0 and 3.1 Standards - Confused yet?

There is no need to be. There are four iterations of the USB PD standard. USB PD 1.0 is a rather basic version providing fixed power profiles, whereas the newer PD 2.0, 3.0 and 3.1 revisions are more dynamic and provide greater flexibility.

USB Power Delivery 1.0

Profile	Voltage	Current	Power	Supported devices
1	5 V	2 A	10 W	smartphones, hard drives, small accessories
2	12 V	1.5 A	18 W	smartphones, tablets, Ultrabooks™, larger accessories
3	12 V	3 A	36 W	future smartphones, notebooks, displays, hubs
4	20 V	3 A	60 W	larger notebooks, hubs, docking stations
5	20 V	5 A	100 W *	workstations, hubs, external graphic cards

Claim	Identification

USB Power Delivery 2.0/3.0

Profile	Voltage	Current	Power	Supported devices
1	5 V	0.1 - 3.0 [A]	10 W	headphones, small accessories
2	9 V	1.67 - 3.0 [A]	15 - 27 W	smartphones, cameras and drones
3	15 V	1.8 - 3.0 [A]	27 - 45 W	tablets, and small laptops
4	20 V	2.25 - 3.0 [A] 3.0 - 5.0 [A] *	45 - 100 W	large laptops and displays

* Requires specially rated **100 W USB-C charging cable**

USB Power Delivery 3.1

The USB PD 3.1 specification divides power into two ranges: Standard Power (SPR), which is the current USB PD3.0 standard with a maximum charging power of 100 W and Extended Power (EPR) with three newly added voltages of 28 V, 36 V, and 48 V. The maximum output current to the three voltages is still 5 A, while the maximum output power can reach 240 W.

Profile	Voltage	Current	Power	Supported devices
5	28 V	3.57 - 5.0 [A] *	140 W	displays, gaming laptops
6	36 V	3.89 - 5.0 [A] *	180 W	displays, gaming laptops
7	48 V	3.75 - 5.0 [A] *	240 W	displays, gaming laptops, desktop PCs

* Requires specially rated 240 W USB-C charging cable

See, e.g., USB-C Power Delivery, Manhattan Products, https://manhattanproducts.eu/pages/usb-c-pd-charging-everything-you-need-to-know.

EXHIBIT J

Exhibit J - U.S. Patent No. 8,545,247

Claims	Identification
1[pre] A dock for receiving a portable electronic device, comprising:	To the extent the preamble is limiting, the Nintendo-branded devices include a dock for receiving a portable electronic device. The Nintendo-branded devices area dock:  See?e.g., *https://www.nintendo.com/us/store/products/nintendo-switch-dock-105663/*

	The the Nintendo-branded devices receive a portable electronic device:  *https://www.ifixit.com/Guide/Nintendo+Switch+Dock+Circuit+Board+Replacement/146408*
1[a] a housing comprising an aperture;	The Nintendo-branded devices include a housing comprising an aperture. The Nintendo-branded devices include a housing:

	 *https://gtrusted.com/nintendo-switch-dock* The housing comprises an aperture.

	  *https://gameusagi.com/2017/02/more-on-the-inside-of-the-nintendo-switch-dock/ (left); Photo taken of Nintendo Switch Dock (right) (Model HAC-002(-01)).*
1[b] a support coupled to an inner wall of the housing, a portion of the support being elastically deformable;	The Nintendo-branded devices include a support coupled to an inner wall of the housing, a portion of the support being elastically deformable. The Nintendo-branded devices include a support coupled to an inner wall of the housing.

	  https://gameusagi.com/2017/02/more-on-the-inside-of-the-nintendo-switch-dock/ *(left); Photo taken of Nintendo Switch Dock (right) (Model HAC-002(-01)).*

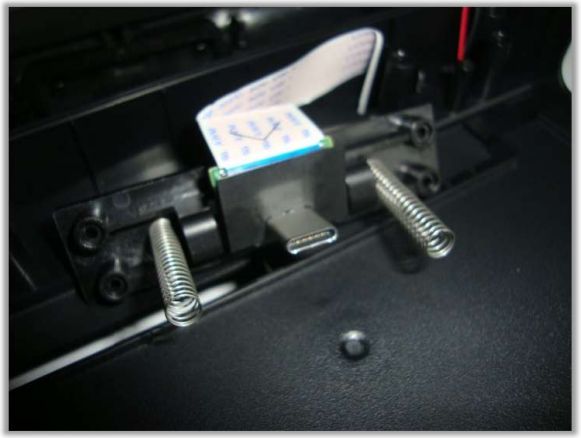
Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).

The Nintendo-branded devices include a portion of the support being elastically deformable.

Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).

	  *Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).*
1[c] a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for	The Nintendo-branded devices include a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device, wiring of the connector for transferring data from the portable electronic device.

transferring data from the portable electronic device; and	The Nintendo-branded devices include a connector received in the support and extending through the aperture for electrically communicating with the portable electronic device.   *https://gameusagi.com/2017/02/more-on-the-inside-of-the-nintendo-switch-dock/ (left); Photo taken of Nintendo Switch Dock (right) (Model HAC-002(-01)).*

	The Nintendo-branded devices include wiring of the connector for transferring data from the portable electronic device.  *Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).*
1[d] a collar abutting the connector within the housing to limit translation of the connector, the connector being pivotable relative to the collar;	The Nintendo-branded devices include a collar abutting the connector within the housing to limit translation of the connector, the connector being pivotable relative to the collar. The Nintendo-branded devices include a collar abutting the connector within the housing to limit translation of the connector.

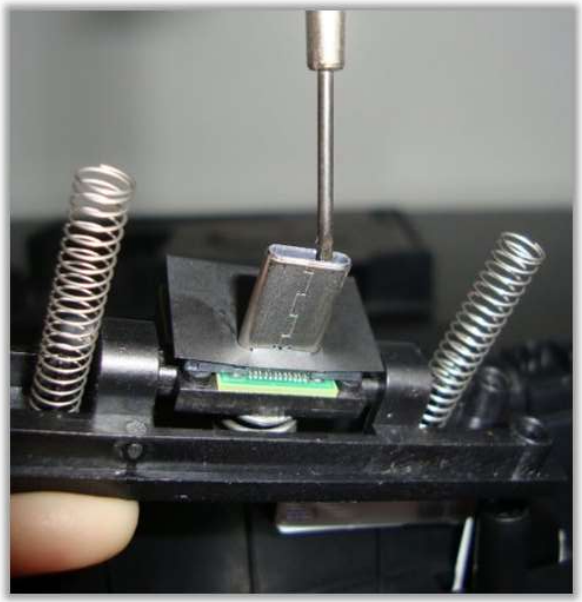


Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).

The Nintendo-branded devices include the connector being pivotable relative to the collar.

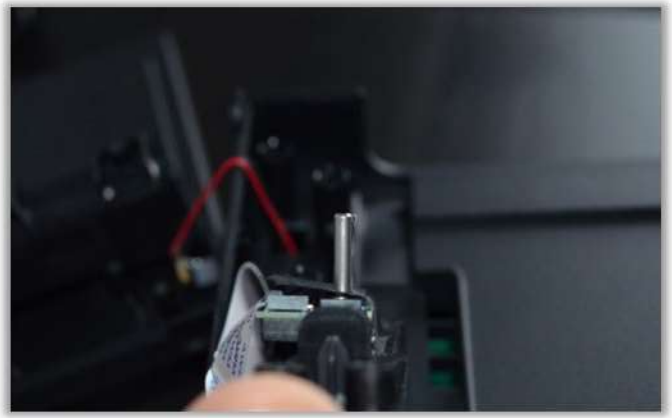
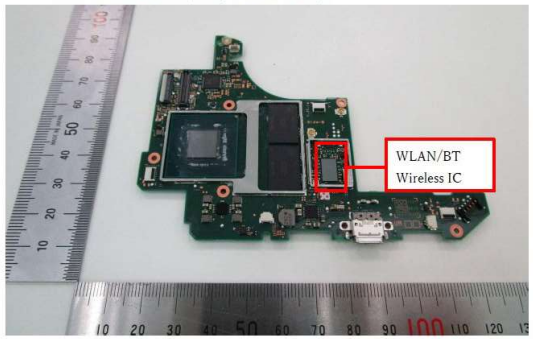


Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).

1[e] wherein the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.	In the Nintendo-branded devices, the portion of the support elastically deforms in response to non-axial movement of at least a portion of the connector.  *Photo taken of Nintendo Switch Dock (Model HAC-002(-01)).*

EXHIBIT K

Exhibit K Nintendo – U.S. Patent No. 7,529,305

Claim	Identification
1 [pre] A transmitter adapted to process a plurality M of symbol substreams, the transmitter comprising:	To the extent the preamble is limiting the Nintendo-branded devices include a transmitter adapted to process a plurality M of symbol substreams. The Nintendo Switch/Switch Lite/Switch OLED comprises a transmitter implemented by an Infineon/Cypress/Broadcom 4356 wireless IC. **20. High Throughput (HT) PHY specification** **20.1.1 Introduction to the HT PHY** In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 18 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 17 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band Wireless module PCB (Front, Shield removed):  https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337261

Claim	Identification
	How to Connect to a Wireless Network Support | Nintendo Switch **Description:** Information on connecting a Nintendo Switch console to a wireless home network **Additional Information:** Before continuing, it is recommended that you verify the following information for the wireless network: •The SSID (network's name) •The wireless password, if a password is required **Complete These Steps:** 1.Place the Nintendo Switch console within 3 metres (10 feet) of the wireless router to ensure a strong wireless signal. 2.On the Nintendo Switch console, select "System Settings" from the HOME Menu 3.Select "Internet", and then "Internet Settings". 4.The Nintendo Switch console will automatically search for nearby Wi-Fi signals. 5.Select the appropriate network name (SSID) from the list. 6.If you are unable to find your network's name, stand closer to the wireless router and press the Y Button to search again. 7.If the network name is greyed out, this indicates the wireless security type being used is not supported by the Nintendo Switch console. 8.If you are still unable to find your network, this may indicate an issue with the wireless network environment. 9.If prompted, use the on-screen keyboard to enter the network's wireless password. https://www.nintendo.com/en-gb/Support/Nintendo-Switch/FAQ/How-to-Connect-to-a-Wireless-Network-1228927.html

Claim	Identification

IEEE 802.11-2020

19.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

g) STBC encoder spreads constellation points from *NSS* spatial streams into *NSTS* space-time streams using a space-time block code. STBC is used only when ; see 19.3.11.9.2.

h) Spatial mapper maps space-time streams to transmit chains.

19.3.4 Overview of the PPDU encoding process

The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

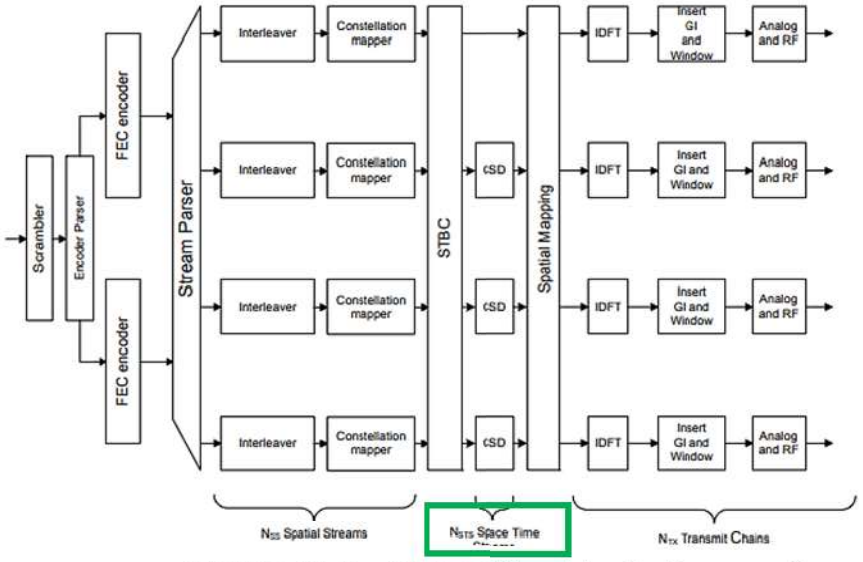
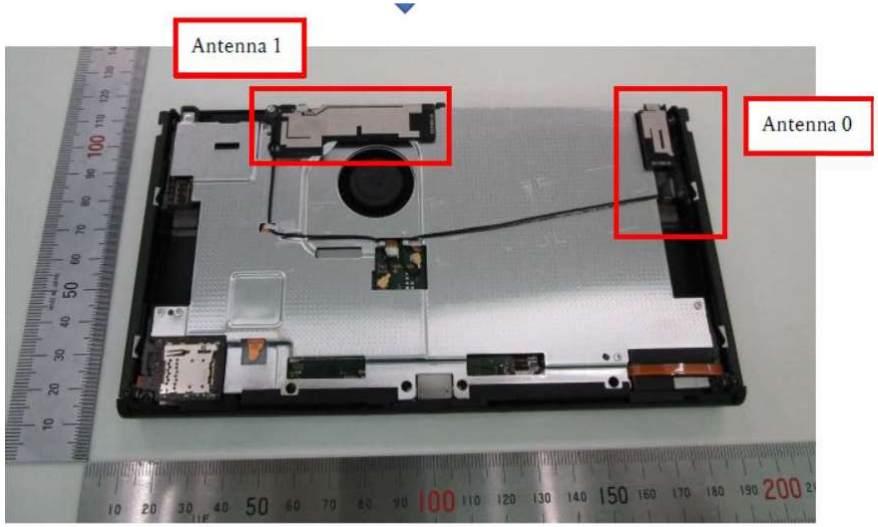


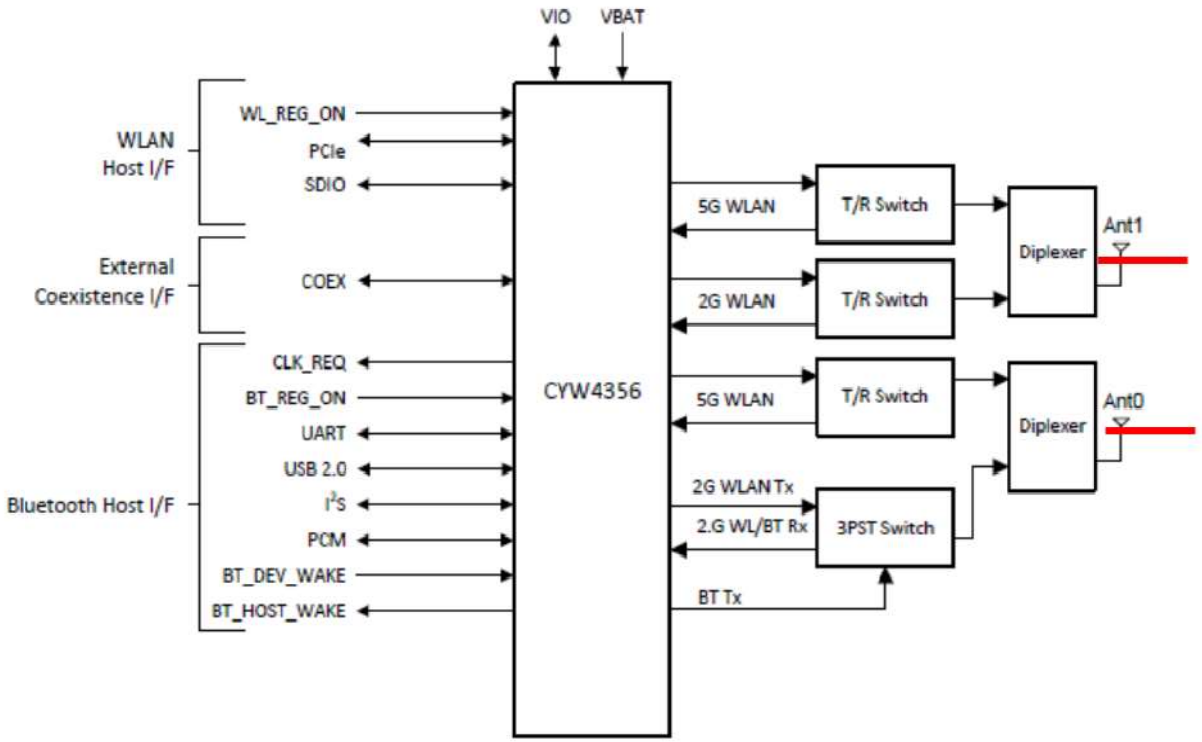
Figure 19-3—Transmitter block diagram 2

Claim	Identification
a space-time coding block adapted to produce M space time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams,	The Nintendo-branded devices include a space-time coding block adapted to produce M space time coded symbols per input set of M symbols, each input set of M symbols comprising one symbol per symbol substream, each of the M space-time coded symbols being included in a respective one of M space-time coded streams. **The Nintendo Switch/Switch Lite/Switch OLED transmits M space-time coded streams using two antennas**  https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337261

Claim	Identification

The Nintendo Switch/Switch Lite/Switch OLED transmits M space-time coded streams using two antennas

Figure 1. Functional Block Diagram



https://www.infineon.com/dgdl/Infineon-CYW4356_CG8674_Single-Chip_5G_WiFi_IEEE_802.11ac_2x2_MAC_Baseband_Radio_with_Integrated_Bluetooth_5.0-DataSheet-v03_00-EN.pdf?fileId=8ac78c8c7d0d8da4017d0ee4c6ad6bfa

Claim	Identification
	1.3 Standards Compliance The CYW4356/CG8674 supports the following standards: ■ Bluetooth 5.0 with Basic Rate (BR), Enhanced Data Rate (EDR) and Bluetooth Low Energy (BLE) ■ IEEE802.11ac mandatory and optional requirements for 20 MHz, 40 MHz, and 80 MHz channels ■ IEEE 802.11n—Handheld Device Class (Section 11) ■ IEEE 802.11a ■ IEEE 802.11b ■ IEEE 802.11g **The Nintendo Switch/Switch Lite/Switch OLED uses the 4356 chip compliant with the 802.11 standards**

Claim	Identification
	IEEE 802.11-2020 **19.3.4 Overview of the PPDU encoding process** The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure: p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated with the corresponding transmit chain. Otherwise, a spatial mapping matrix associated with each OFDM subcarrier, as indicated by the EXPANSION_MAT parameter of the TXVECTOR, is used to perform a linear transformation on the vector of N_{STS} complex numbers associated with each subcarrier in each OFDM symbol. This spatial mapping matrix maps the vector of N_{STS} complex numbers in each subcarrier into a vector of N_{TX} complex numbers in each subcarrier. The sequence of N_{ST} complex numbers associated with each transmit chain (where each of the N_{ST} complex numbers is taken from the same position in the N_{TX} vector of complex numbers across the N_{ST} subcarriers associated with an OFDM symbol) constitutes an OFDM symbol associated with the corresponding transmit chain. For details, see 19.3.11.11 . Spatial mapping matrices may include cyclic shifts, as described in 19.3.11.11.2 .
wherein each symbol of the M symbol substreams is	The Nintendo-branded devices include each symbol of the M symbol substreams is represented in all M space-time coded streams.

Claim	Identification
represented in all M space-time coded streams,	**IEEE 802.11-2020** **19.3.11.11.2 Spatial mapping** If the data to be transmitted on subcarrier k on space-time stream i_{STS} are $X_k^{(i_{STS})}$, the transmitted data on the transmit chain i_{TX} shall be as shown in Equation 19-57 $$r_{Field}^{(i_{TX})} = \frac{1}{\sqrt{N_{STS} \cdot N_{Field}^{Tone}}} w_{T_{Field}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} X_k^{(i_{STS})} \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \quad (20\text{-}57)$$ where $[Q_k]_{i_{TX}, i_{STS}}$ is the element in row i_{TX} and column i_{STS} in a matrix Q_k with N_{TX} rows and N_{STS} columns; Q_k may be frequency dependent *Field* is any field, as defined in 20.3.7, excluding L-STF, L-LTF, L-SIG, and HT-SIG in HT_MF format PPDU Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are: a) *Direct mapping*: Q_k is a diagonal matrix of unit magnitude complex values that takes one of two forms: 1) $Q_k = \mathbf{I}$, the identity matrix 2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k \Delta_F \tau_{CS}^i)$, where τ_{CS}^i, $i = 1, \ldots, N_{TX}$ represents the CSD applied. b) *Indirect mapping:* Q_k may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix. c) *Spatial expansion:* Q_k is the product of a CSD matrix and a square matrix formed of orthogonal columns. As an illustration:
wherein the transmitter comprises a delay arrangement, arranged such that for each symbol of the M symbol substreams a time of	The Nintendo-branded devices include the transmitter comprising a delay arrangement, arranged such that for each symbol of the M symbol substreams a time of representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams.

Claim	Identification
representation of the symbol in the M space-time coded streams is different for each of the M space-time coded streams,	**IEEE 802.11-2020** 19.3.3 Transmitter block diagram HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks: j) Cyclic shift (CSD) insertion is where the insertion of the cyclic shifts prevents unintentional beamforming. CSD insertion may occur before or after the IDFT. There are three cyclic shift types as follows: 1) A cyclic shift specified per transmitter chain with the values defined in Table 19-9 (a possible implementation is shown in Figure 19-2). 2) A cyclic shift specified per space-time stream with the values defined in Table 19-10 (a possible implementation is shown in Figure 19-3). 3) A cyclic shift that may be applied as a part of the spatial mapper; see 19.3.11.11.2.

Claim	Identification

IEEE 802.11-2020

19.3.11.11.2 Spatial Mapping

If the data to be transmitted on subcarrier k on space-time stream i_{STS} are $X_k^{(i_{STS})}$, the transmitted data on the transmit chain i_{TX} shall be as shown in Equation 19-57

$$r_{Field}^{(i_{TX})} = \frac{1}{\sqrt{N_{STS} \cdot N_{Field}^{Tone}}} w_{T_{Field}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} X_k^{(i_{STS})} \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \qquad 19\text{-}57$$

Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are:

a) *Direct mapping*: Q_k is a diagonal matrix of unit magnitude complex values that takes one of two forms:

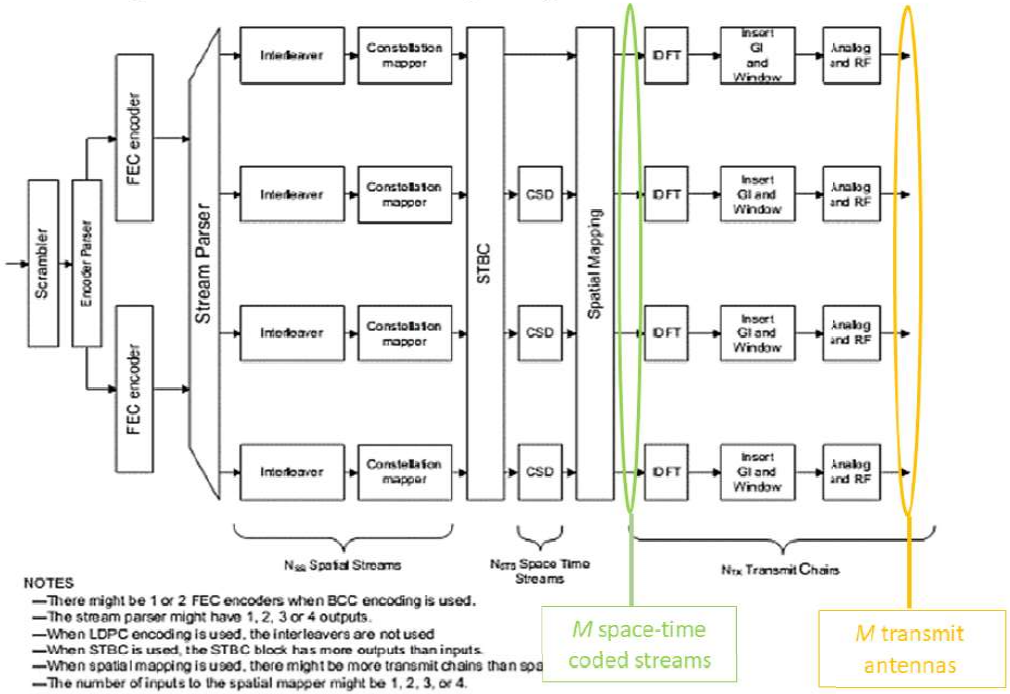
   1) $Q_k = \mathbf{I}$, the identity matrix

   2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k \Delta_F \tau_{CS}^i)$, where $\tau_{CS}^i, i = 1, \ldots, N_{TX}$ represents the CSD applied.

b) *Indirect mapping*: Q_k may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix.

c) *Spatial expansion*: Q_k is the product of a CSD matrix and a square matrix formed of orthogonal columns. As an illustration:

Claim	Identification
each space time coded symbol comprising a representation of a symbol of each of the M symbol substreams;	The Nintendo-branded devices include each space time coded symbol comprising a representation of a symbol of each of the M symbol substreams. Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are: a) *Direct mapping*: Q_k is a diagonal matrix of unit magnitude complex values that takes one of two forms: 1) $Q_k = \mathbf{I}$, the identity matrix 2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k\Delta_F \tau_{CS}^i)$, where τ_{CS}^i, $i = 1, \ldots, N_{TX}$ represents the CSD applied. b) *Indirect mapping:* Q_k may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix. c) *Spatial expansion:* Q_k is the product of a CSD matrix and a square matrix formed of orthogonal columns.
a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams,	The Nintendo-branded devices include a plurality M of transmit antennas each adapted to transmit a respective one of the M space-time coded streams.

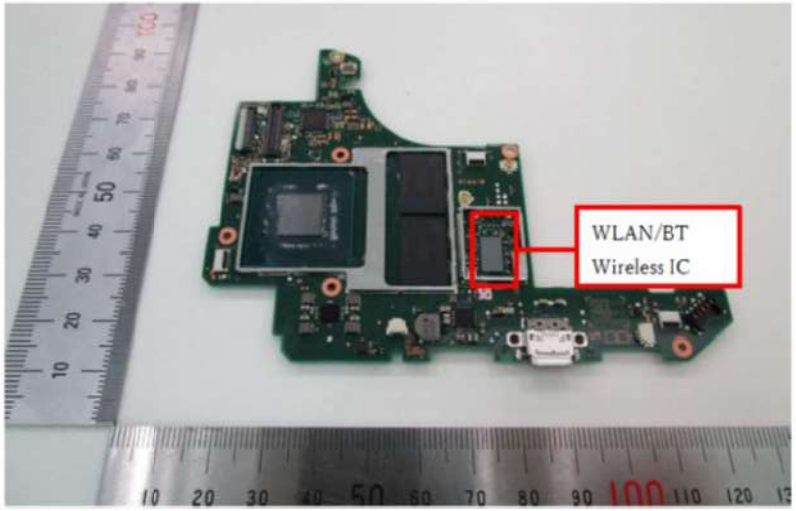
Claim	Identification
	IEEE 802.11-2020 **19.3.4 Overview of the PPDU encoding process** The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:  **Figure 20-3—Transmitter block diagram 2**
such that for each symbol of each input set of M symbols, the M space-time coded symbols that	In the Nintendo-branded devices, for each symbol of each input set of M symbols, the M space-time coded symbols that contain a representation of the symbol are transmitted at different times.

Claim	Identification
contain a representation of the symbol are transmitted at different times.	**IEEE 802.11-2020** **19.3.11.11.2 Spatial mapping** If the data to be transmitted on subcarrier k on space-time stream i_{STS} are $X_k^{(i_{STS})}$, the transmitted data on the transmit chain i_{TX} shall be as shown in Equation 19-57 $$r_{Field}^{(i_{TX})} = \frac{1}{\sqrt{N_{STS} \cdot N_{Field}^{Tone}}} w_{T_{Field}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \sum_{i_{STS}=1}^{N_{STS}} [Q_k]_{i_{TX}, i_{STS}} X_k^{(i_{STS})} \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{STS}})) \quad 19\text{-}57$$ Below are examples of spatial mapping matrices that might be used. There exist many other alternatives; implementation is not restricted to the spatial mapping matrices shown. The examples are: a) *Direct mapping*: Q_k is a diagonal matrix of unit magnitude complex values that takes one of two forms: 1) $Q_k = \mathbf{I}$, the identity matrix 2) A CSD matrix in which the diagonal elements represent cyclic shifts in the time domain: $[Q_k]_{i,i} = \exp(-j2\pi k \Delta_F \tau_{CS}^i)$, where τ_{CS}^i, $i = 1, \ldots, N_{TX}$ represents the CSD applied. b) *Indirect mapping:* Q_k may be the product of a CSD matrix and a unitary matrix such as the Hadamard matrix or the Fourier matrix. c) *Spatial expansion:* Q_k is the product of a CSD matrix and a square matrix formed of orthogonal columns. As an illustration:

EXHIBIT L

Exhibit L Nintendo – U.S. Patent No. 9,313,065

Claim	Identification
1. A method of transmitting symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames at an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers	To the extent the preamble is limiting, the Nintendo-branded devices include a method of transmitting symbols using Orthogonal Frequency Division Multiplexing, OFDM, frames at an OFDM transmitter having at least two transmitting antennas, the OFDM frames having a time domain and a frequency domain, each OFDM frame comprising a plurality of OFDM symbols in the time domain and a plurality of sub-carriers in the frequency domain. For example, the Nintendo Switch/Switch Lite/Switch OLED transmits symbols using OFDM frames implemented by an Infineon/Cypress/Broadcom 4356 wireless IC. **IEEE 802.11-2020** **19 High Throughput (HT) PHY specification** **19.1.1 Introduction to the HT PHY** In addition to the requirements found in Clause 19 an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 17 hen the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 16 nd Clause 18 vhen the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band **19.3.3 Transmitter block diagram** HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks: **19.3.4 Overview of the PPDU encoding process** The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure: a) Determine the number of transmit chains, N_{TX}, from the N_TX field of the TXVECTOR. Produce the PLCP preamble training fields for each of the N_{TX} transmit chains based on the FORMAT, NUM_EXTEN_SS, CH_BANDWIDTH, and MCS parameters of the TXVECTOR. The format and p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation,

Claim	Identification
in the frequency domain, the method comprising the steps of:	**The Nintendo Switch/Switch Lite/Switch OLED comprises an HT STA implemented by an Infineon/Cypress/Broadcom 4356 wireless IC** **19 High Throughput (HT) PHY specification** **19.1.1 Introduction to the HT PHY** In addition to the requirements found in Clause 19 an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows: — In Clause 17 hen the HT STA is operating in a 20 MHz channel width in the 5 GHz band — In Clause 16 nd Clause 18 vhen the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band Wireless module PCB (Front, Shield removed):  https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337261

Claim	Identification

The Nintendo Switch/Switch Lite/Switch OLED comprises an HT STA implemented by an Infineon/Cypress/Broadcom 4356 wireless IC

19 High Throughput (HT) PHY specification

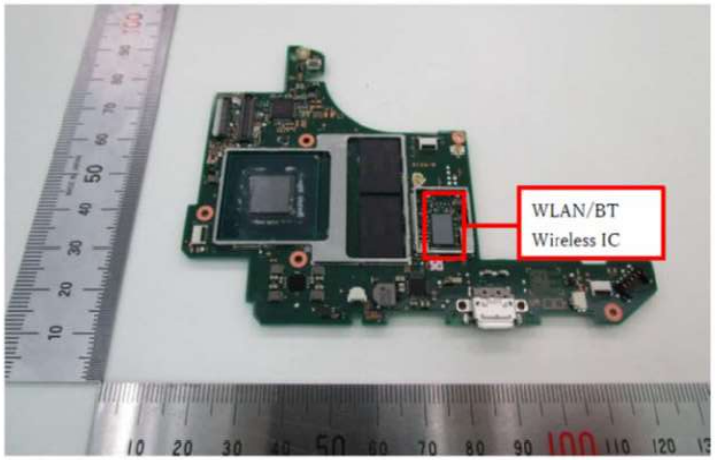
19.1.1 Introduction to the HT PHY

In addition to the requirements found in Clause 19 an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:

— In Clause 17 hen the HT STA is operating in a 20 MHz channel width in the 5 GHz band

— In Clause 16 nd Clause 18 vhen the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

Wireless module PCB (Front, Shield removed):



https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337261

Claim	Identification

The Nintendo Switch/Switch Lite/Switch OLED transmits symbols using OFDM frames

Radio Specification

Wireless LAN, Bluetooth (BR / EDR / Low Energy function) part:

Equipment Type	:	Transceiver
Frequency of Operation	:	Wireless LAN part: (2.4 GHz): 2412 MHz – 2472 MHz, (U-NII-1): 5180 MHz – 5240 MHz, (U-NII-2A): 5260 MHz – 5320 MHz, (U-NII-2C): 5500 MHz – 5700 MHz, (U-NII-3): 5745 MHz- 5825 MHz, Bluetooth (BR / EDR / Low Energy) part: 2402 MHz - 2480 MHz
Radio part clock frequency	:	37.4 MHz
Channel spacing	:	Wireless LAN part: (2.4 GHz): 5 MHz, (5 GHz): 20 MHz, Bleutooth part: (BR / EDR): 1 MHZ, (Low Energy): 2 MHz
Type of modulation	:	Wireless LAN part: 2.4 GHz band: DBPSK, DQPSK, CCK, OFDM 5 GHz band: OFDM

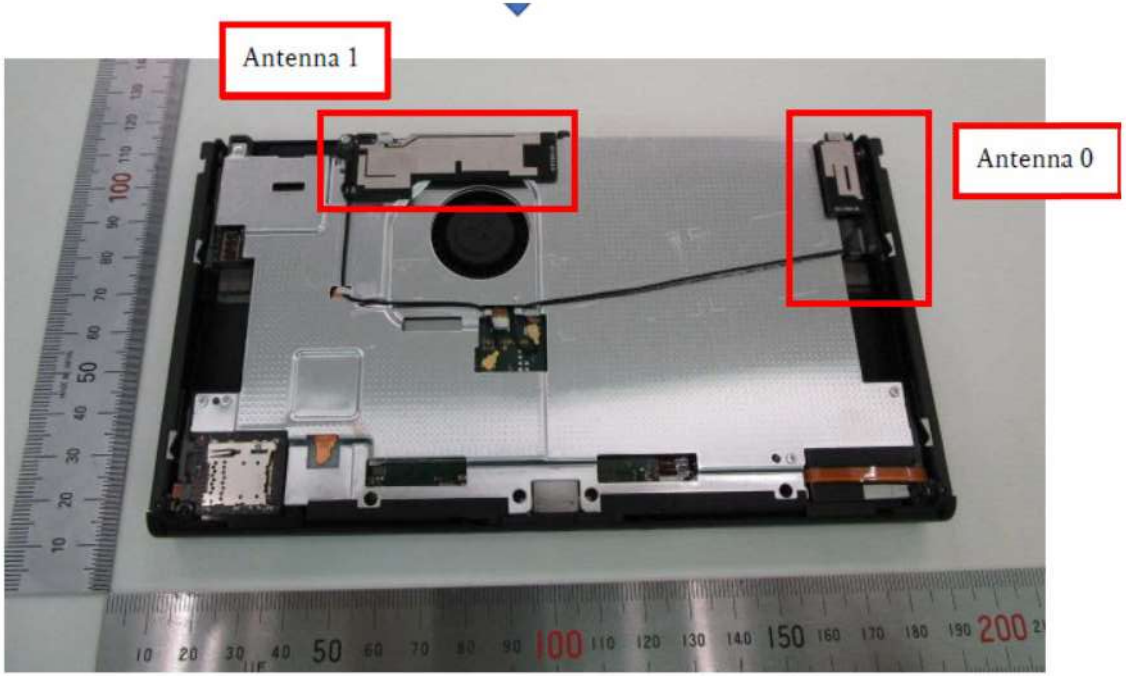
https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337247

Claim	Identification
	The Nintendo Switch/Switch Lite/Switch OLED transmits symbols using OFDM frames when the wireless internet connection is set up using the instructions indicated below:

Activating and Deactivating Wireless Internet Connection

To activate wireless internet connection, go to INTERNET in (System Settings) on the HOME Menu and proceed to set up a connection. To deactivate wireless internet connection in handheld mode, hold down the HOME Button to enter Quick Settings, then set Flight Mode to On. Alternatively, in handheld mode, start (System Settings) from the HOME Menu, then set Flight Mode to On.

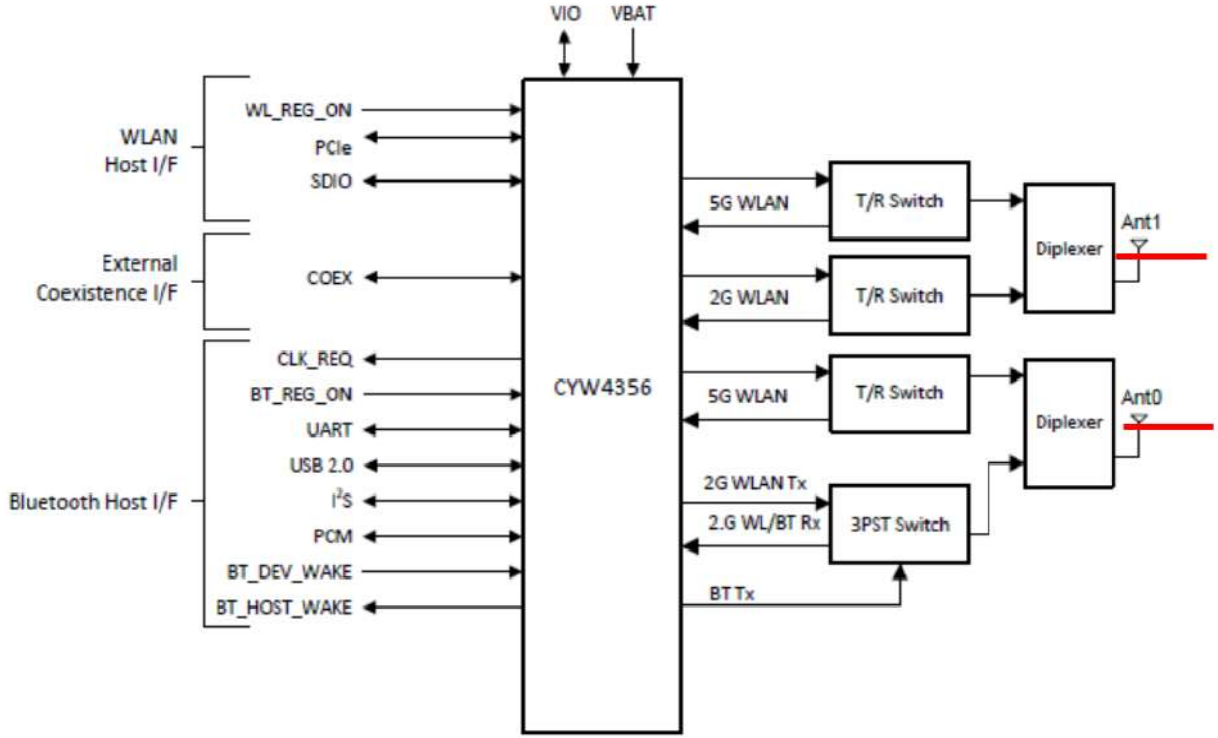
https://www.nintendo.com/eu/media/downloads/support_1/nintendoswitch/NSwitch_ImportantInformation_UKV_01.pdf

Claim	Identification
	The Nintendo Switch/Switch Lite/Switch OLED transmits using two antennas  https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337261

Claim	Identification

The Nintendo Switch/Switch Lite/Switch OLED transmits using two antennas

Figure 1. Functional Block Diagram



https://www.infineon.com/dgdl/Infineon-CYW4356_CG8674_Single-Chip_5G_WiFi_IEEE_802.11ac_2x2_MAC_Baseband_Radio_with_Integrated_Bluetooth_5.0-DataSheet-v03_00-EN.pdf?fileId=8ac78c8c7d0d8da4017d0ee4c6ad6bfa

Claim	Identification

IEEE 802.11-2020

19 High Throughput (HT) PHY specification

19.1.1 Introduction to the HT PHY

In addition to the requirements found in Clause 19 n HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:

— In Clause 17 ıen the HT STA is operating in a 20 MHz channel width in the 5 GHz band

— In Clause 16 ıd Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction (FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.

19.3.3 Transmitter block diagram

p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation, $N_{TX} = N_{STS}$, and there is a one-to-one correspondence between space-time streams and transmit chains. In this case, the OFDM symbols associated with each space-time stream are also associated

Claim	Identification
	The Nintendo Switch/Switch Lite/Switch OLED uses the 4356 chip compliant with the following 802.11 standards

1.3 Standards Compliance

The CYW4356/CG8674 supports the following standards:

- Bluetooth 5.0 with Basic Rate (BR), Enhanced Data Rate (EDR) and Bluetooth Low Energy (BLE)
- IEEE802.11ac mandatory and optional requirements for 20 MHz, 40 MHz, and 80 MHz channels
- IEEE 802.11n—Handheld Device Class (Section 11)
- IEEE 802.11a
- IEEE 802.11b
- IEEE 802.11g
- IEEE 802.11d
- IEEE 802.11h
- IEEE 802.11i
- Security:
  - WEP
  - WPA Personal
  - WPA2 Personal
  - WMM
  - WMM-PS (U-APSD)
  - WMM-SA
  - AES (Hardware Accelerator)
  - TKIP (HW Accelerator)
  - CKIP (SW Support)
- Proprietary Protocols:
  - CCXv2
  - CCXv3
  - CCXv4
  - CCXv5
- IEEE 802.15.2 Coexistence Compliance—on silicon solution compliant with IEEE 3 wire requirements

The CYW4356/CG8674 will support the following future drafts/standards:

- IEEE 802.11w—Secure Management Frames
- A4WP Wireless Power Transfer System Baseline System Specification V1.0
- IEEE 802.11 Extensions:
  - IEEE 802.11e QoS Enhancements (In accordance with the WMM specification, QoS is already supported.)
  - IEEE 802.11h 5 GHz Extensions
  - IEEE 802.11i MAC Enhancements
  - IEEE 802.11k Radio Resource Measurement

https://www.infineon.com/dgdl/Infineon-CYW4356_CG8674_Single Chip_5G_WiFi_IEEE_802.11ac_2x2_MAC_Baseband_Radio_with_Integrated_Bluetooth_5.0-DataSheet-v03_00-EN.pdf?fileId=8ac78c8c7d0d8da4017d0ee4c6ad6bfa

Claim	Identification
transmitting, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and transmitting, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern,	The Nintendo-branded devices transmit, on an OFDM symbol, pilot symbols corresponding to the first antenna using a scattered pattern; and transmit, on the OFDM symbol, pilot symbols corresponding to the second antenna using the scattered pattern **The Nintendo Switch/Switch Lite/Switch OLED transmits pilot symbols on first and second antennas using a scattered pattern in accordance with 802.11 when the Switch is connected to an 802.11 access point based on the instructions indicated below:** **How to Connect to a Wireless Network** Support | Nintendo Switch **Description:** Information on connecting a Nintendo Switch console to a wireless home network **Additional Information:** Before continuing, it is recommended that you verify the following information for the wireless network: •The SSID (network's name) •The wireless password, if a password is required **Complete These Steps:** 1.Place the Nintendo Switch console within 3 metres (10 feet) of the wireless router to ensure a strong wireless signal. 2.On the Nintendo Switch console, select "System Settings" from the HOME Menu 3.Select "Internet", and then "Internet Settings". 4.The Nintendo Switch console will automatically search for nearby Wi-Fi signals. 5.Select the appropriate network name (SSID) from the list. 6.If you are unable to find your network's name, stand closer to the wireless router and press the Y Button to search again. 7.If the network name is greyed out, this indicates the wireless security type being used is not supported by the Nintendo Switch console. 8.If you are still unable to find your network, this may indicate an issue with the wireless network environment. 9.If prompted, use the on-screen keyboard to enter the network's wireless password. https://www.nintendo.com/en-gb/Support/Nintendo-Switch/FAQ/How-to-Connect-to-a-Wireless-Network-1228927.html

Claim	Identification

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19.3.11.10 Pilot subcarriers

In a 20 MHz transmission four pilot tones shall be inserted in the same subcarriers used in Clause 17, i.e., in subcarriers –21, –7, 7, and 21. The pilot sequence for the n^{th} symbols and $i_{STS}{}^{\text{th}}$ space-time stream shall be as shown in Equation (19-54).

$$P^{-28,28}_{(i_{STS},n)} = \{0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,n \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+1) \bmod 4},0,0,0,0,0,0,0,$$
$$0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+2) \bmod 4},0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+3) \bmod 4},0,0,0,0,0,0,0\} \quad (19\text{-}54)$$

where $n \oplus a$ indicates symbol number modulo integer a and the patterns $\Psi^{(N_{STS})}_{i_{STS},n}$ are defined in Table 20-19 and Table 20-20.

NOTE—For each space-time stream, there is a different pilot pattern, and the pilot patterns are cyclically rotated over symbols.

Claim	Identification

IEEE 802.11-2020

19.3.11.10 Pilot subcarriers

In a 40 MHz transmission (excluding MCS 32; see 19.3.11.11.5), pilot signals shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot sequence for symbol n and space-time stream i_{STS} shall be as shown in Equation (19-55).

$$P^{-58,58}_{(i_{STS},\,n)} = \{0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,n \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,$$
$$0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+1) \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+2) \bmod 6},0,0,0,0,0,0,0,0,0,$$
$$0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+3) \bmod 6},0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+4) \bmod 6},$$
$$0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,\Psi^{(N_{STS})}_{i_{STS},\,(n+5) \bmod 6},0,0,0,0,0\} \quad (19\text{-}55)$$

where the patterns are defined in Table 19-19 and Table 19-20.

NOTE—For each space-time stream, there is a different pilot pattern, and the pilot patterns are cyclically rotated over symbols.

Claim	Identification

The Switch passed testing by the FCC for transmission on two antennas

4.1 Operating Mode(s)

*1) Test operating mode was determined as follows according to "Section 1 of 6 802.11 a/b/g/n testing - Managing Complex Regulatory Approvals - " of TCB Council Workshop October 2009 and also was judged the necessity of 802.11ac mode by the pre-test.

Test item	Mode	Tested frequency	Worst data rate *2)	Antenna *2)
Conducted emission, Radiated emission (below 1 GHz), Out of band emissions (Conducted) *1)	Transmitting (Tx), IEEE 802.11ac VHT20 (11ac-20), SISO	5260 MHz	MCS 3, PN9	0
26 dB Emission Bandwidth, 20 dB Bandwidth, Occupied Bandwidth (99%), Maximum Conducted Output Power, Maximum Power Spectral Density	Transmitting (Tx), IEEE 802.11a (11a)	(Low bands): 5180 MHz, 5220 MHz, 5240 MHz, (Middle bands): 5260 MHz, 5300 MHz, 5320 MHz (Additional bands): 5500 MHz, 5580 MHz, 5700 MHz, (Upper bands): 5745 MHz, 5785 MHz, 5825 MHz	48 Mbps, PN9	0
	Transmitting (Tx), IEEE 802.11n HT20 (11n-20), SISO	(Low bands): 5180 MHz, 5220 MHz, 5240 MHz, (Middle bands): 5260 MHz, 5300 MHz, 5320 MHz (Additional bands): 5500 MHz, 5580 MHz, 5700 MHz, (Upper bands): 5745 MHz, 5785 MHz, 5825 MHz	MCS 3, PN9	0
	Transmitting (Tx), IEEE 802.11n HT20 (11n-20), MIMO	(Low bands): 5180 MHz, 5220 MHz, 5240 MHz, (Middle bands): 5260 MHz, 5300 MHz, 5320 MHz (Additional bands): 5500 MHz, 5580 MHz, 5700 MHz, (Upper bands): 5745 MHz, 5785 MHz, 5825 MHz	MCS11, PN9	0 & 1
	Transmitting (Tx), IEEE 802.11ac VHT20 (11ac-20), SISO	(Low bands): 5180 MHz, 5220 MHz, 5240 MHz, (Middle bands): 5260 MHz, 5300 MHz, 5320 MHz (Additional bands): 5500 MHz, 5580 MHz, 5700 MHz, (Upper bands): 5745 MHz, 5785 MHz, 5825 MHz	MCS 3, PN9	0
	Transmitting (Tx), IEEE 802.11ac VHT20 (11ac-20), MIMO	(Low bands): 5180 MHz, 5220 MHz, 5240 MHz, (Middle bands): 5260 MHz, 5300 MHz, 5320 MHz (Additional bands): 5500 MHz, 5580 MHz, 5700 MHz, (Upper bands): 5745 MHz, 5785 MHz, 5825 MHz	MCS 3, PN9	0 & 1

https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=5337247

Claim	Identification
wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code.	In the Nintendo-branded devices, wherein the pilot symbols for the first antenna correspond to a first code and the pilot symbols for the second antenna correspond to a second code. **IEEE 802.11-2020** **19.3.11.10 Pilot Subcarriers** **Table 19-19 Pilot values for 20 MHz transmission** N_{STS} | i_{STS} | $\Psi^{(N_{STS})}_{i_{STS},0}$ | $\Psi^{(N_{STS})}_{i_{STS},1}$ | $\Psi^{(N_{STS})}_{i_{STS},2}$ | $\Psi^{(N_{STS})}_{i_{STS},3}$ 1 | 1 | 1 | 1 | 1 | −1 2 | 1 | 1 | 1 | −1 | −1 2 | 2 | 1 | −1 | −1 | 1 3 | 1 | 1 | 1 | −1 | −1 3 | 2 | 1 | −1 | 1 | −1 3 | 3 | −1 | 1 | 1 | −1 4 | 1 | 1 | 1 | 1 | −1 4 | 2 | 1 | 1 | −1 | 1 4 | 3 | 1 | −1 | 1 | 1 4 | 4 | −1 | 1 | 1 | 1 First antenna, first code: i_{STS}=1 (red) Second antenna, second code: i_{STS}=2 (green) A code is comprised of a sequence of phase shifts in each row. Each row is referred to as a code.

Claim	Identification

IEEE 802.11-2020

19.3.11.10 Pilot Subcarriers

Table 19-20—Pilots values for 40 MHz transmission (excluding MCS 32)

N_{STS}	i_{STS}	$\Psi^{(N_{STS})}_{i_{STS},0}$	$\Psi^{(N_{STS})}_{i_{STS},1}$	$\Psi^{(N_{STS})}_{i_{STS},2}$	$\Psi^{(N_{STS})}_{i_{STS},3}$	$\Psi^{(N_{STS})}_{i_{STS},4}$	$\Psi^{(N_{STS})}_{i_{STS},5}$
1	1	1	1	1	−1	−1	1
2	1	1	1	−1	−1	−1	−1
2	2	1	1	1	−1	1	1
3	1	1	1	−1	−1	−1	−1
3	2	1	1	1	−1	1	1
3	3	1	−1	1	−1	−1	1

Claim	Identification

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20.3.4 Overview of the PPDU encoding process

The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

o) Determine whether 20 MHz or 40 MHz operation is to be used from the CH_BANDWIDTH parameter of the TXVECTOR. Specifically, when CH_BANDWIDTH is HT_CBW20 or NON_HT_CBW20, 20 MHz operation is to be used. When CH_BANDWIDTH is HT_CBW40 or NON_HT_CBW40, 40 MHz operation is to be used. For 20 MHz operation (with the exception of non-HT formats), insert four subcarriers as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers, N_{ST}, is 56. For 40 MHz operation (with the exception of MCS 32 and non-HT duplicate format), insert six subcarriers as pilots into positions –53, –25, –11, 11, 25, and 53, resulting in a total of N_{ST} = 114 subcarriers. See 19.3.11.11.5 for pilot locations when using MCS 32 and 19.3.11.12 for pilot locations when using non-HT duplicate format. The pilots are modulated using a pseudorandom cover sequence. Refer to 19.3.11.10 for details. For 40 MHz operation, apply a +90° phase shift to the complex value in each OFDM subcarrier with an index greater than 0, as described in 19.3.11.11.4, 19.3.11.11.5, and 19.3.11.12.

p) Map each of the complex numbers in each of the N_{ST} subcarriers in each of the OFDM symbols in each of the N_{STS} space-time streams to the N_{TX} transmit chain inputs. For direct-mapped operation,