IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF OHIO
EASTERN DIVISION AT COLUMBUS

NEO WIRELESS, LLC, *Plaintiff*, v. AMERICAN HONDA MOTOR CO., INC. & HONDA DEVELOPMENT & MANUFACTURING OF AMERICA, LLC, *Defendants*.	§ § § § § § § § § § § §	CIVIL ACTION NO.: 2:22-cv-01824 JURY TRIAL DEMANDED

PLAINTIFF NEO WIRELESS, LLC'S COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff Neo Wireless, LLC ("Neo Wireless," "Neo," or "Plaintiff"), brings this action for patent infringement under 35 U.S.C. § 271 against Defendants American Honda Motor Co., Inc. ("HMC") and Honda Development & Manufacturing of America, LLC ("HDMA") (collectively, "Honda," "Honda Defendants," or "Defendants"). Plaintiff alleges, based upon its own personal knowledge with respect to its own actions and based upon information and belief with respect to all others' actions, as follows:

THE PARTIES

1. Plaintiff Neo Wireless, LLC is a Delaware corporation with its principal place of business located in Wayne, Pennsylvania.

2. On information and belief, Defendant American Honda Motor Co. is a corporation organized and existing under the laws of the State of California with its principal place of business at 1919 Torrance Boulevard, Torrance, California, 90501. HMC may be served through its

registered agent, Corporation Service Company, 50 West Broad Street, Suite 1330, Columbus, Ohio 43215.

3. On information and belief, Honda Development & Manufacturing of America, LLC is a corporation organized and existing organized and existing under the laws of the State of Ohio with its principal place of business at 24000 Honda Parkway, Marysville, Ohio 43040. HDMA may be served through its registered agent, Corporation Service Company, 50 West Broad Street, Suite 1330, Columbus, Ohio 43215.

JURISDICTION AND VENUE

4. This action arises under the Patent Act, 35 U.S.C. § 1 *et seq*.

5. Subject matter jurisdiction is proper in this Court under 28 U.S.C. §§ 1331 and 1338(a).

6. Venue in this District is proper under 28 U.S.C. § 1400(b) because, on information and belief, each Honda entity (1) has committed acts of infringement in this District and (2) has a regular and established place of business in this District.

7. This Court has general jurisdiction over HDMA because its principal place of business is in the forum state.

8. Defendants are also subject to this Court's specific personal jurisdiction due at least to each Honda Defendant's substantial business activities in the State and within this District, including: (1) at least a portion of the infringements alleged herein; and/or (2) regularly doing or soliciting business, engaging in other persistent courses of conduct, and/or deriving substantial revenue from goods and services provided to individuals in Ohio and in this District.

9. Honda maintains facilities throughout the state of Ohio and this District, including at least the following: HMC operates an engine plant at 12500 Meranda Road, Anna, Ohio 45302

that serves as the flagship of the Acura brand, the Honda Accord, and represents the largest of its Ohio operations with a facility spanning over 4 million square feet;[1] HMC also operates an automobile plant and transportation research center located at 11000 OH-347, East Liberty, Ohio 43319 which encompasses much of Honda's research and development including $124 million state-of-the-art wind tunnel facility, new technology in testing capabilities for Honda's vehicles, including the accused products, 110,000 square feet of space.[2] HMC operates an automobile and motorcycle plant at 24000 Honda Parkway, Marysville, Ohio 43040. HMC similarly maintains a regular and established place of business through its transmission plant at 6964 OH-235, Russells Point, Ohio 43348 and its Honda Rider Education Center and parts center located at 101 S Stanfield Rd, Troy, Ohio 45373.

10. HDMA's principal place of business is located within this District. On information and belief, HDMA operates a research and development center at 21001 OH-739, Raymond, Ohio 43067 where HDMA engages in research, development, testing, and designing of Honda products, including the Accused Products.[3]

11. Defendants do and intend to do business in Ohio and in this District, directly or through intermediaries, and offer their products and/or services, including those accused herein of infringement, to customers and potential customers located in Ohio and in this District.

12. Defendants, both directly and through their subsidiaries or intermediaries (including distributors, retailers, and others), have purposefully and voluntarily placed one or more infringing products and/or services, as described below, into the stream of commerce with the

[1] *See* https://ohio.honda.com/our-operations.
[2] *See* https://hondanews.com/en-US/releases/honda-opens-new-world-class-wind-tunnel-in-ohio.
[3] *See* https://ohio.honda.com/.

expectation that those products will be purchased and used by customers and/or consumers in the Southern District of Ohio.

13. These infringing products and/or services have been and continue to be made, used, sold, offered for sale, purchased, and/or imported by customers and/or consumers in the Southern District of Ohio.

14. Defendants have placed the Accused Products into the stream of commerce by selling and/or offering to sell the Accused Products in the Southern District of Ohio, shipping Accused Products into the Southern District of Ohio, and/or shipping Accused Products knowing that those products would be shipped into the Southern District of Ohio.

THE ASSERTED PATENTS

I. The ’366 Patent

15. On June 18, 2013, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 8,467,366 (“the ’366 patent”), entitled “Methods and Apparatus for Random Access in Multi-Carrier Communication Systems.” A copy of the ’366 patent is attached as Exhibit 1.

16. The ’366 patent issued from U.S. Patent Application 13/205,579, which was filed by Neocific Inc. on August 8, 2011 and was assigned from the inventors to Waltical Solutions, Inc. on April 8, 2005. The application was later assigned from Waltical Solutions, Inc. to Neocific, Inc. on December 14, 2005. The now-issued ’366 patent was assigned from Neocific, Inc. to CFIP NCF LLC on November 22, 2019 before it was assigned to Neo Wireless LLC on January 23, 2020.

17. The ’366 patent is valid and enforceable.

II. The ’908 Patent

18. On April 17, 2018, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 10,833,908 (“the ’908 patent”), entitled “Channel Probing Signal for a Broadband Communication System.” A copy of the ’908 patent is attached as Exhibit 2.

19. The ’908 patent issued from U.S. Patent Application 16/902,740, which was filed on June 16, 2020 by Neo Wireless LLC on behalf of the inventors.

20. The ’908 patent is valid and enforceable.

III. The ’941 Patent

21. On September 11, 2018, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 10,075,941 (“the ’941 patent”), entitled “Methods and Apparatus for Multi-Carrier Communications With Adaptive Transmission and Feedback.” A copy of the ’941 patent is attached as Exhibit 3.

22. The ’941 patent issued from U.S. Patent Application 15/082,878, which filed by Neocific, Inc. on March 28, 2016. The now-issued ’941 patent was assigned from Neocific, Inc. to CFIP NCF LLC on November 22, 2019 before it was assigned to Neo Wireless LLC on January 23, 2020.

23. The ’941 patent is valid and enforceable.

IV. The ’450 Patent

24. On October 15, 2019, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 10,447,450 (“the ’450 patent”), entitled “Method and System for Multi-Carrier Packet Communication with Reduced Overhead.” A copy of the ’450 patent is attached as Exhibit 4.

25. The ’450 patent issued from U.S. Patent Application 15/676,421, which was filed by Neocific, Inc. on August 14, 2017. The now-issued ’450 patent was later assigned from Neocific, Inc. to CFIP NCF LLC on November 22, 2019 before it was assigned to Neo Wireless LLC on January 23, 2020.

26. The ’450 patent is valid and enforceable.

V. The ’512 Patent

27. On March 30, 2021, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 10,965,512 (“the ’512 patent”), entitled “Method and Apparatus Using Cell-Specific and Common Pilot Subcarriers in Multi-Carrier, Multi Cell Wireless Communication Networks.” A copy of the ’512 patent is attached as Exhibit 5.

28. The ’512 patent issued from U.S. Patent Application 17/012,813, which was filed by Neo Wireless on September 4, 2020.

29. The ’512 patent is valid and enforceable.

VI. The ’302 Patent

30. On September 8, 2020, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 10,771,302 (“the ’302 patent”), entitled “Channel Probing Signal for a Broadband Communication System.” A copy of the ‘302 patent is attached as exhibit 6.

31. The ’302 patent issued from U.S. Patent Application 15/953,950, which was filed on April 16, 2019 and was assigned by Neocific, Inc. to CFIP NCF LLC on November 22, 2019 before it was assigned to Neo Wireless LLC on January 23, 2020.

32. The ’302 patent is valid and enforceable.

33. Neo Wireless owns all rights, title, and interest in and to each of the ’366, ’908, ’941, ’450, ’512, and ’302 patents (the “Patents-in-Suit”) and possesses all rights of recovery.

FACTUAL ALLEGATIONS

34. Inventor Xiaodong (Alex) Li, Ph.D. founded Neocific Inc. in the early 2000s to design, develop, and implement a new wireless communication system. He and his co-inventors had extensive experience with wireless communications systems, including the development of the Wi-Max standards, and a deep understanding of the flaws in existing systems at the time. The inventors saw an opportunity to create a new wireless communication system meant to address those flaws while incorporating cutting-edge Orthogonal Frequency-Division Multiple Access (OFDMA) based technologies, and, starting in the 2004-2005 timeframe, they filed patents on the work.

35. Dr. Li served as the President and Founder of Neocific. Dr. Li obtained his Ph.D. in electrical engineering from the University of Washington, his M.S. from Shanghai Jiao Tong University, and his B.S. from Tsinghua University. Dr. Li has authored more than 30 journal and conference papers in wireless communications, video coding, and networking. He has been granted more than 100 U.S. and foreign patents.

36. Dr. Titus Lo, Ph.D. is a founding employee of Neocific. Dr. Lo obtained his Ph.D. in electrical engineering from McMaster University and his B.S. from the University of British Columbia. Dr. Lo has authored more than 30 technical papers in international peer-reviewed journals and presented more than 50 time at industry events. He has been granted more than 100 U.S. and foreign patents.

37. Neo Wireless owns all substantial right, title, and interest in the Patents-in-Suit, and holds the right to sue and recover damages for infringement thereof.

38. David Loo is the CEO of Plaintiff Neo Wireless. Mr. Loo works and resides in Wayne, Pennsylvania. Mr. Loo has over a decade of experience as a licensing executive and patent

attorney with a well-established track record of assisting companies, inventors and patent holders to ensure they are fairly compensated for their inventions.

39. The wireless communication industry has been developing rapidly since Bell Labs developed the First Generation of modern commercial cellular technology in 1984. Multiple wireless communication technologies designated by generations emerged and brought new capacities to people all over the world. In 2008, 3GPP created and finalized the LTE standards as an upgrade to 3G. The cellular industry recognized its major benefits, and virtually all cellular device manufacturers have embraced LTE as the next generation of commercial cellular technology and developed phones, hotspots, and other cellular-connectivity devices to utilize the 4G LTE technology.

40. Automakers have implemented this cellular communications technology into its vehicles. For example, telematics systems first debuted in 1996 through OnStar using analog cell networks, which allowed consumers to receive remote diagnostics, remotely unlock vehicles, and receive emergency services including aid after a collision. In 2007, 3G technology emerged bringing greater speed and capacity to these features allowing automakers to design more advanced functions.

41. At least as far back as 2015, Honda began implementing the newest 4G LTE cellular technology into Honda's accused products. 4G LTE technology provided for 10 times faster data speeds, increased responsiveness, and the ability to support voice and data connections simultaneously. 4G LTE connection further provides consumers with a variety of in-vehicle wi-fi hot spots and vast entertainment options. As a result, Honda could better support a variety of wireless features including SOS emergency assistance, automatic collision notification, stolen

vehicle tracking, roadside assistance, remote start, remote climate control adjustment, navigation map updates, live traffic data, and wi-fi hotspot, etc.

42. Honda provides 4G LTE connectivity in its various Honda brands, including the accused products, via the HondaLink system integrated into the accused products.

43. Building on these 4G LTE capabilities, Honda develops and utilizes the HondaLink mobile app that allows owners of its vehicles to interact with their vehicles from their cellular devices. Features on this app include the ability to remotely start, lock, or unlock the vehicle, or to monitor the vehicle's condition.

44. Honda models that implement 4G/LTE communications—including but not limited to the Odyssey, Pilot, and Passport models—as well as those that may in the future implement 4G/LTE or 5G/NR capabilities, are collectively referred to herein as the "Accused Products."

45. As described above, the Asserted Patents read onto portions of the LTE or 4G/5G standards, which Honda implements in the Accused Products.

46. Honda does not have any rights to the Patents-in-Suit.

47. Neo Wireless is entitled to past damages for Honda's infringement of the Patents-in-Suit. Neo Wireless has complied with 35 U.S.C. § 287. Neo Wireless does not make, offer for sale, or sell within the United States any patented article under the Asserted Patents. Additionally, Neo Wireless provided Honda with actual notice of its infringement prior to the filing of this lawsuit, or at a minimum by the filing of this Complaint.

48. In the interest of providing detailed averments of infringement, Neo Wireless has identified below at least one claim per patent to demonstrate infringement. However, the selection of claims should not be considered limiting, and additional claims of the Patents-in-Suit (including

method, system, and apparatus claims) that are infringed by Honda will be disclosed in compliance with the Court's rules related to infringement contentions.

ALLEGATIONS OF PATENT INFRINGEMENT

49. Neo Wireless incorporates by reference the preceding paragraphs as if fully set forth herein.

50. As set forth below, Honda's Accused Products incorporate, without any license from Neo Wireless, LTE, 4G, and 5G technology protected by patents owned by Neo Wireless. Neo Wireless respectfully seeks relief from this Court for Honda's infringement.

51. Honda has directly infringed, and continues to directly infringe, the Asserted Patents under 35 U.S.C. § 271(a) by making, using, selling and/or offering to sell, in this District and elsewhere in the United States, and/or importing into this District and elsewhere in the United States, one or more of Honda's Accused Products, that is, certain infringing vehicles outfitted with instrumentalities that infringe the Asserted Patents, as further described in detail in Counts I-VI *infra*.

52. Honda has indirectly infringed the Asserted Patents under 35 U.S.C. § 271(b) by inducing infringement by others, such as its subsidiaries, dealerships, distributors, retailers, and end-user customers, by, for example, implementing the infringing features in its cellular-capable products, encouraging its users to take advantage of 4G/LTE and/or 5G/NR features within the United States, and/or instructing, dictating, or training its dealerships and customers to use the infringing features.

53. Similarly, Honda's advertising, sales, design, development, and/or technical materials related to the 3GPP LTE/4G and/or 5G/NR standards associated with the Accused Products contained and continue to contain instructions, directions, suggestions, and/or invitations

that invite, entice, lead on, influence, encourage, prevail on, move by persuasion, and/or cause its subsidiaries, distributors, retailers, dealerships, customers, and the public to directly infringe at least one claim of each of the Patents-in-Suit, either literally or under the doctrine of equivalents.

54. Honda took the above actions intending to cause infringing acts by others.

55. Honda received actual notice of its infringement of the Asserted Patents as early as November 30, 2021, and at least as early as the date of service of this Complaint. Therefore, Honda was or is now aware of the Asserted Patents or has willfully blinded itself as to the existence of the Asserted Patents and the Accused Products' infringement thereof.

56. Further, Honda has made, used, sold, offered to sell, imported and/or encouraged the making, using, selling, offering to sell, or importing of Honda's Accused Products despite knowing of an objectively high likelihood that its actions constituted infringement of the Asserted Patents at all times relevant to this suit. Alternatively, Honda subjectively believed there was a high probability that others would infringe the Asserted Patents but took deliberate steps to avoid confirming that it was actively inducing infringement by others.

57. For the reasons described above, Honda's infringement of the Asserted Patents has been willful.

58. Honda's acts of infringement have caused damage to Neo Wireless. Neo Wireless is entitled to recover from Honda the damages incurred by Neo Wireless as a result of Honda's wrongful acts.

COUNT ONE: INFRINGEMENT OF THE '366 PATENT

59. Plaintiff incorporates the allegations of all of the foregoing paragraphs as if fully restated herein.

60. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

61. Each of Honda's Accused Products implement the portions of the 3GPP LTE standard specification that read on at least claim 1 of the '366 patent. *See* Exhibit 7.

62. Honda's Accused Products therefore meet at least one claim of the '366 patent.

63. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '366 patent and infringe under 35 U.S.C. § 271(a)–(b) in ways analogous to Honda's current infringement described above.

64. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '366 patent.

COUNT TWO: INFRINGEMENT OF THE '908 PATENT

65. Neo Wireless incorporates the allegations of the foregoing paragraphs as if fully restated herein.

66. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

67. Each of Honda's Accused Products implement the portions of the 3GPP LTE standard specification that read on at least claim 11 of the '908 patent. *See* Exhibit 8.

68. Honda's Accused Products therefore meet at least one claim of the '908 patent.

69. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '908 patent and infringe under 35 U.S.C. § 271(a)-(b) in ways analogous to Honda's current infringement described above.

70. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '908 patent.

COUNT THREE: INFRINGEMENT OF THE '941 PATENT

71. Neo Wireless incorporates the allegations of the foregoing paragraphs as if fully restated herein.

72. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

73. Each of Honda's Accused Products implement the portions of the 3GPP LTE standard specification that read on at least claim 13 of the '941 patent. *See* Exhibit 9.

74. Honda's Accused Products therefore meet at least one claim of the '941 patent.

75. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '941 patent and infringe under 35 U.S.C. § 271(a)-(b) in ways analogous to Honda's current infringement described above.

76. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '941 patent.

COUNT FOUR: INFRINGEMENT OF THE '450 PATENT

77. Plaintiff incorporates the allegations of all of the foregoing paragraphs as if fully restated herein.

78. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

79. Each of Honda's Accused Products implements the portions of the 3GPP LTE standard specification that read on at least claim 7 of the '450 patent. *See* Exhibit 10.

80. Honda's Accused Products therefore meet at least one claim of the '450 patent.

81. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '450 patent and infringe under 35 U.S.C. § 271(a)–(b) in ways analogous to Honda's current infringement described above.

82. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '450 patent.

COUNT FIVE: INFRINGEMENT OF THE '512 PATENT

83. Plaintiff incorporates the allegations of all of the foregoing paragraphs as if fully restated herein.

84. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

85. Each of Honda's Accused Products implements the portions of the 3GPP LTE standard specification that read on at least claim 15 of the '512 patent. *See* Exhibit 11.

86. Honda's Accused Products therefore meet at least one claim of the '512 patent.

87. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '512 patent and infringe under 35 U.S.C. § 271(a)–(b) in ways analogous to Honda's current infringement described above.

88. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '512 patent.

COUNT SIX: INFRINGEMENT OF THE '302 PATENT

89. Plaintiff incorporates the allegations of all of the foregoing paragraphs as if fully restated herein.

90. As described above, Honda has infringed and continues to infringe the Asserted Patents by implementing and using 4G/LTE and/or 5G/NR cellular functionality in the Accused Products, and performing the acts of infringement described above.

91. Each of Honda's Accused Products implements the portions of the 3GPP LTE standard specification that read on at least claim 23 of the '302 patent. *See* Exhibit 12.

92. Honda's Accused Products therefore meet at least one claim of the '302 patent.

93. To the extent that Honda releases any new version of its Accused Products, such instrumentalities will meet the claims of the '302 patent and infringe under 35 U.S.C. § 271(a)–(b) in ways analogous to Honda's current infringement described above.

94. Neo Wireless has been damaged and continues to be damaged by Honda's infringement of the '302 patent.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff respectfully requests the following relief:

a. a judgment in favor of Plaintiff that Defendants have infringed, either literally and/or under the doctrine of equivalents, the Asserted Patents;

b. a judgment that Defendants' infringement has been and is willful;

c. a judgment and order requiring Defendants to pay Plaintiff its damages, costs, expenses, and any enhanced damages to which Plaintiff is entitled for Defendant's infringement;

d. a judgment and order requiring Defendants to provide an accounting and to pay

supplemental damages to Plaintiff, including without limitation, pre-judgment and post-judgment interest;

e. a judgment and order requiring Defendants to pay ongoing royalties;

f. a judgment and order finding that this is an exceptional case within the meaning of 35 U.S.C. § 285 and awarding Plaintiff its reasonable attorney fees against Defendants; and

g. any and all other relief as the Court may deem appropriate and just under the circumstances.

DEMAND FOR JURY TRIAL

Pursuant to Fed. R. Civ. P. 38, Plaintiff hereby demands trial by jury on all claims and issues so triable.

DATED: March 29, 2022

Respectfully submitted,

SAND, SEBOLT & WERNOW CO., LPA

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ATTORNEYS FOR PLAINTIFF
NEO WIRELESS LLC

Exhibit 1

US008467366B2

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

(10) **Patent No.: US 8,467,366 B2**
(45) **Date of Patent: *Jun. 18, 2013**

(54) **METHODS AND APPARATUS FOR RANDOM ACCESS IN MULTI-CARRIER COMMUNICATION SYSTEMS**

(75) Inventors: **Xiaodong Li**, Kirkland, WA (US); **Titus Lo**, Bellevue, WA (US); **Kemin Li**, Bellevue, WA (US); **Haiming Huang**, Bellevue, WA (US)

(73) Assignee: **Neocific, Inc.**, Bellevue, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 149 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/205,579**

(22) Filed: **Aug. 8, 2011**

(65) **Prior Publication Data**

US 2011/0292881 A1 Dec. 1, 2011

Related U.S. Application Data

(63) Continuation of application No. 10/583,158, filed as application No. PCT/US2005/008169 on Mar. 9, 2005, now Pat. No. 7,995,967.

(60) Provisional application No. 60/551,589, filed on Mar. 9, 2004.

(51) **Int. Cl.**
H04Q 7/216 (2006.01)

(52) **U.S. Cl.**
USPC **370/342**; 370/329

(58) **Field of Classification Search**
USPC 370/342
See application file for complete search history.

(56) **References Cited**

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7,995,967	B2	8/2011	Li et al.	
2010/0111017	A1 *	5/2010	Um et al.	370/329

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KR	20060055636	A	5/2006

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International Search Report and Written Opinion; International Patent Application No. PCT/US05/08169; Filed Mar. 9, 2005; Applicant: Waltical Solutions, Inc.; Mailed Jun. 9, 2005; 9 pages.

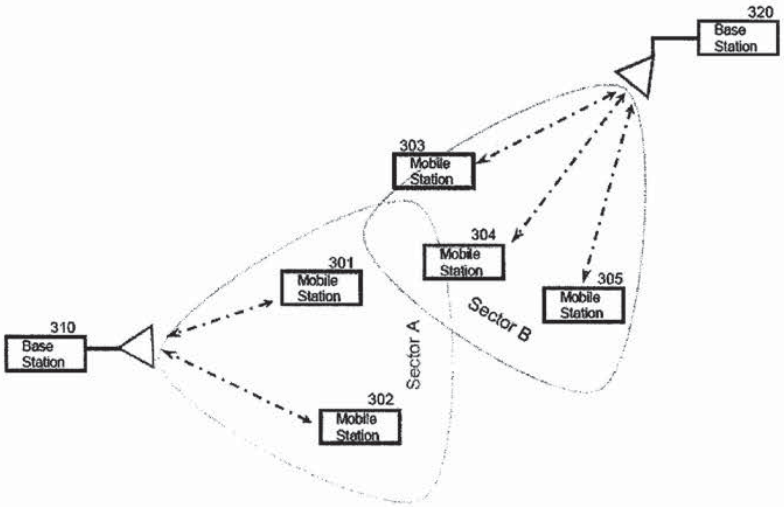
* cited by examiner

Primary Examiner — Ajibola Akinyemi
(74) *Attorney, Agent, or Firm* — Perkins Coie LLP

(57) **ABSTRACT**

Methods and apparatus in a multi-carrier cellular wireless network with random access improve receiving reliability and reduce interference of uplink signals of a random access, while improving the detection performance of a base station receiver by employing specifically configured ranging signals.

24 Claims, 8 Drawing Sheets



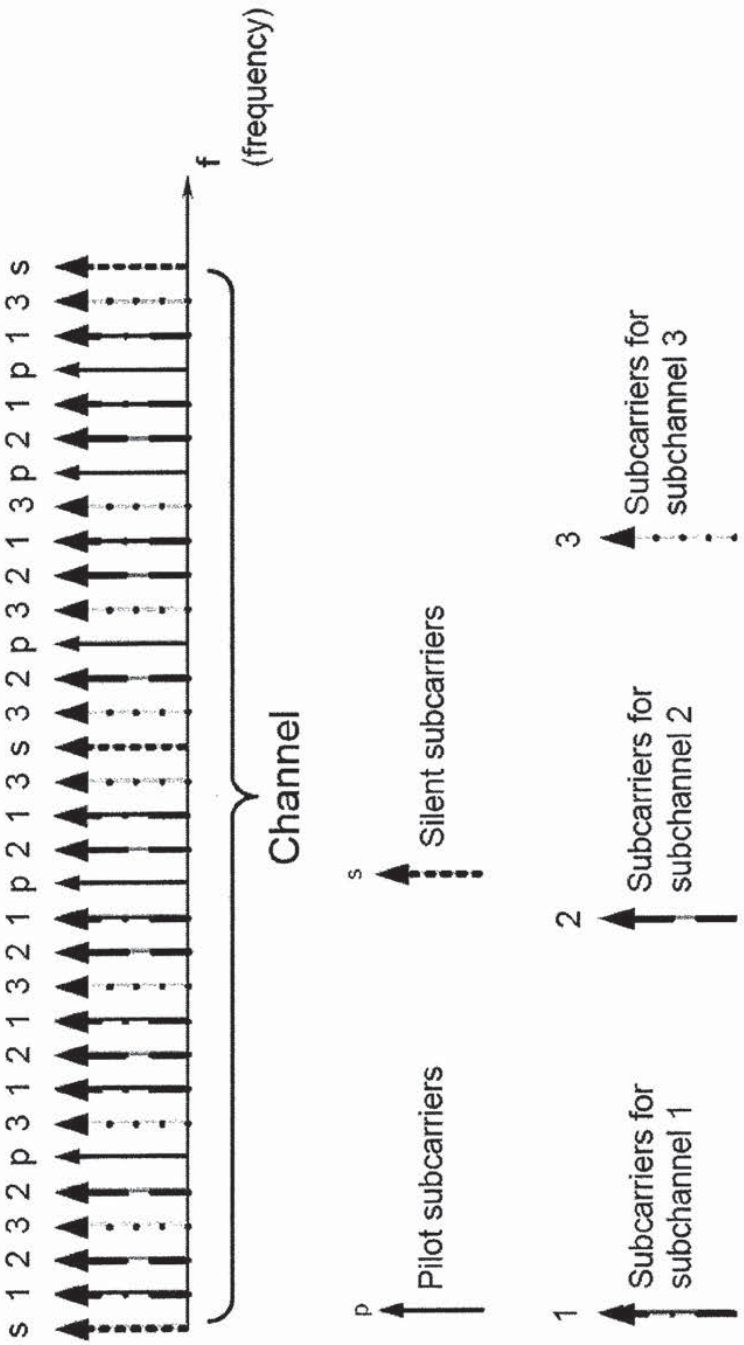

s 1 2 3 2 p 3 1 2 1 3 2 1 p 2 1 3 s 3 2 p 3 2 1 3 p 2 1 p 1 3 s
f
(frequency)
Channel
p
Pilot subcarriers
s
Silent subcarriers
1
Subcarriers for subchannel 1
2
Subcarriers for subchannel 2
3
Subcarriers for subchannel 3

FIG. 1

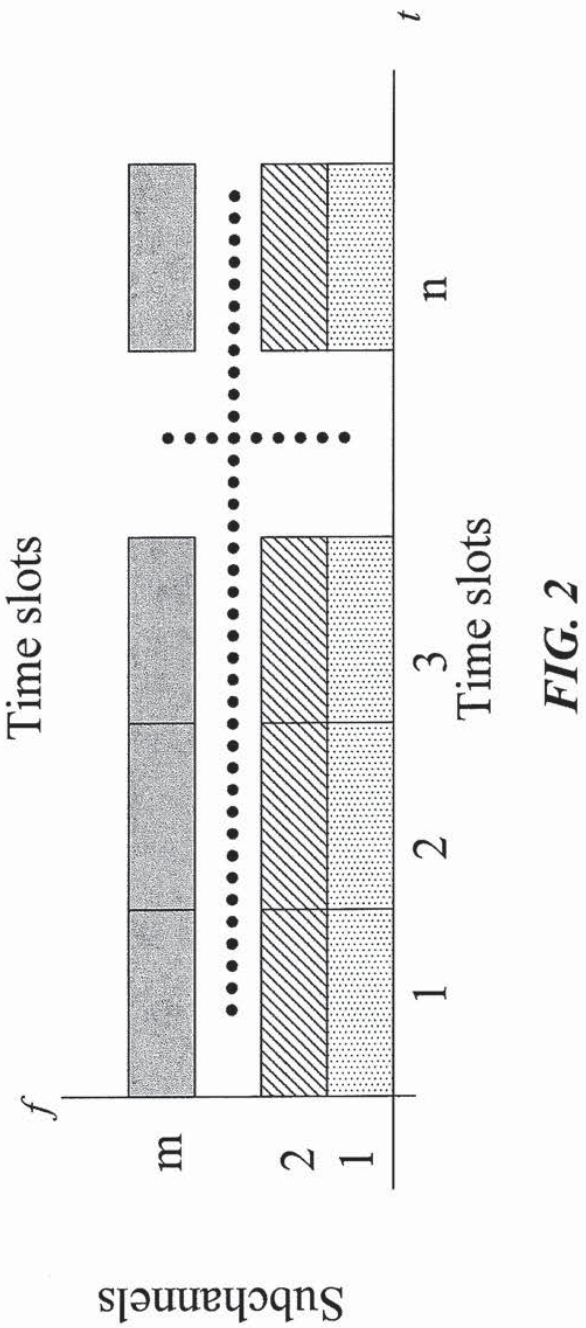


FIG. 2

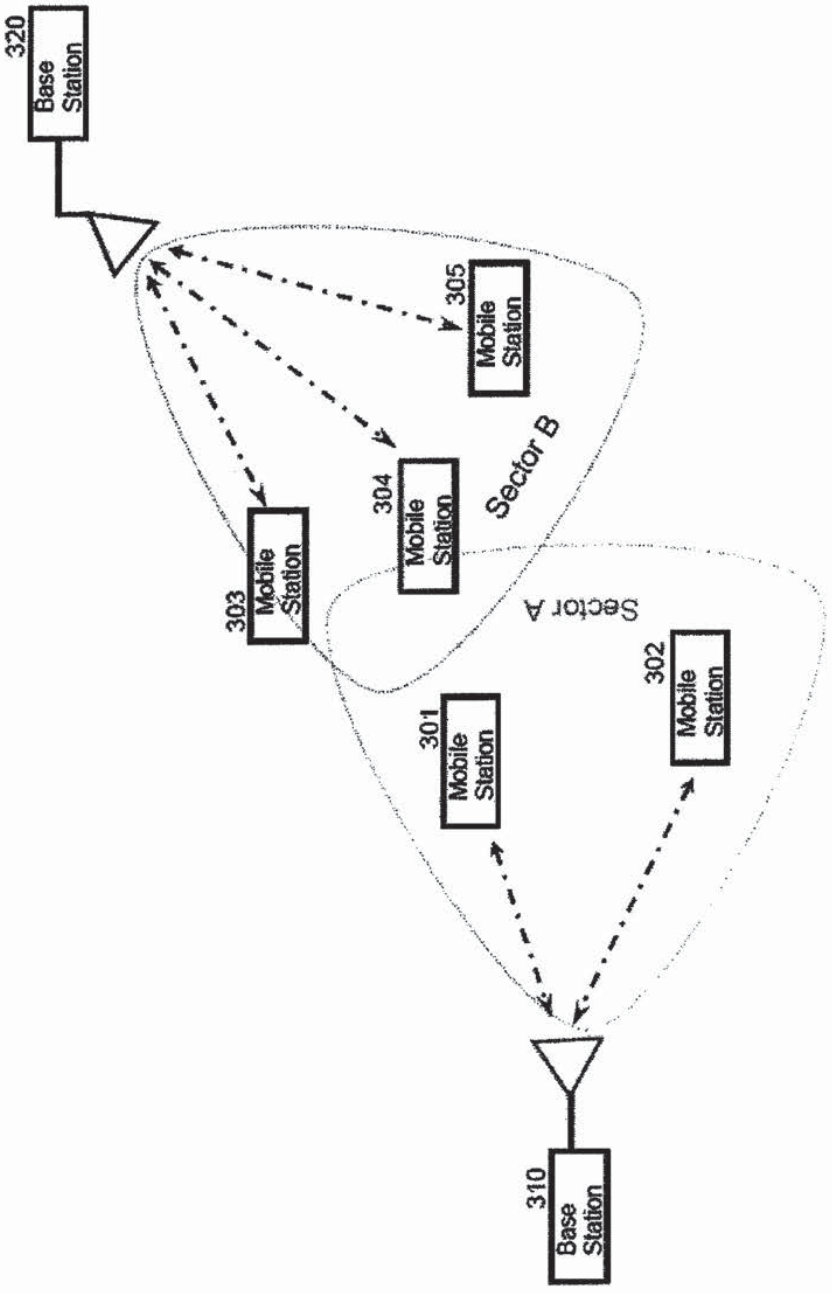

320
Base Station
305
Mobile Station
304
Mobile Station
303
Mobile Station
Sector B
Sector A
302
Mobile Station
301
Mobile Station
310
Base Station

FIG. 3

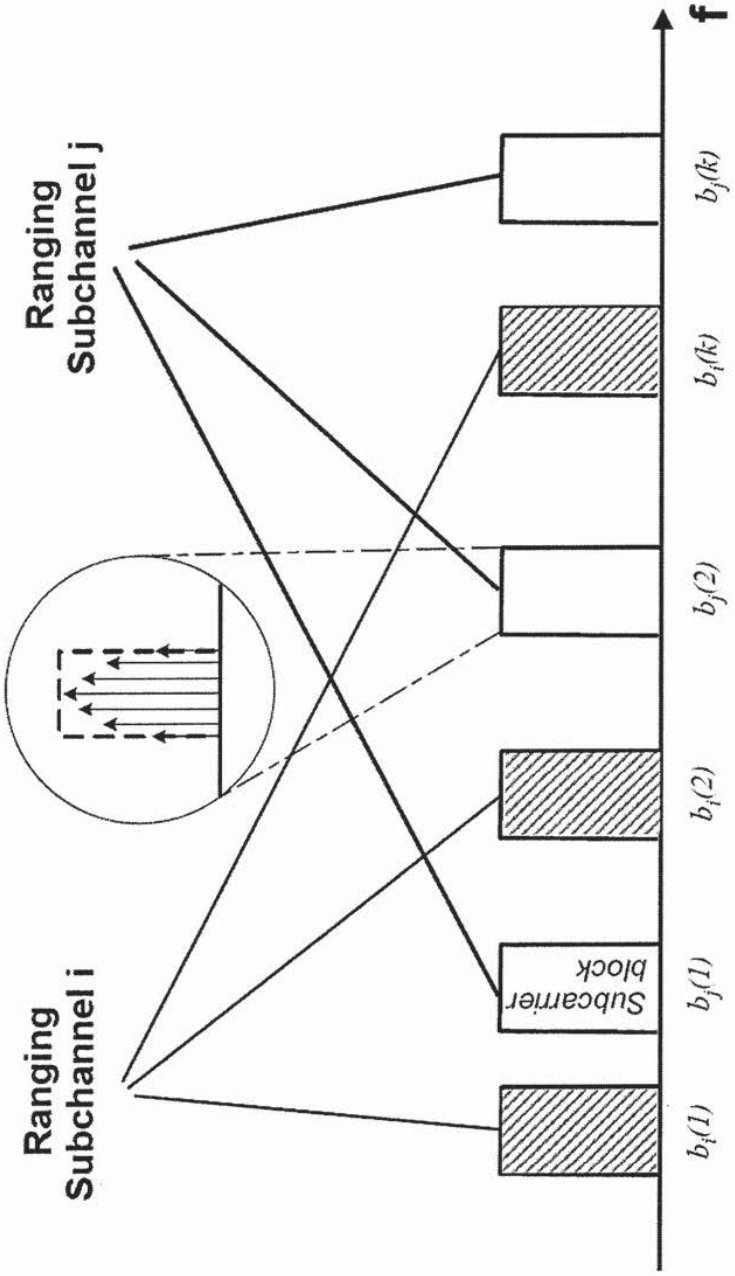

f
Ranging Subchannel j
Ranging Subchannel i
Subcarrier block
$b_j(k)$
$b_i(k)$
$b_j(2)$
$b_i(2)$
$b_j(1)$
$b_i(1)$

FIG. 4

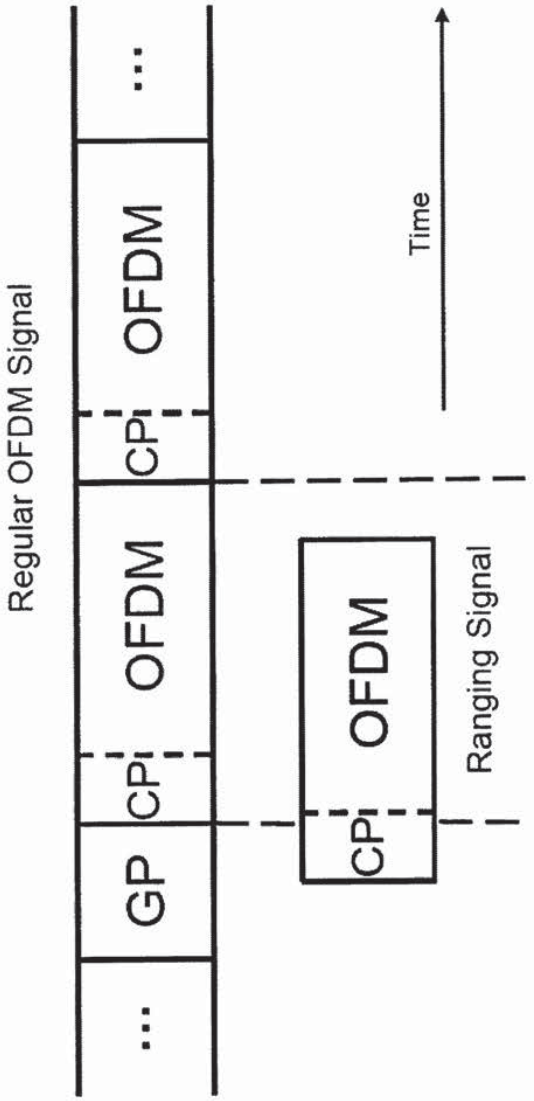

Regular OFDM Signal
Time
Ranging Signal
...
OFDM
CP
OFDM
CP
GP
...
OFDM
CP

FIG. 5

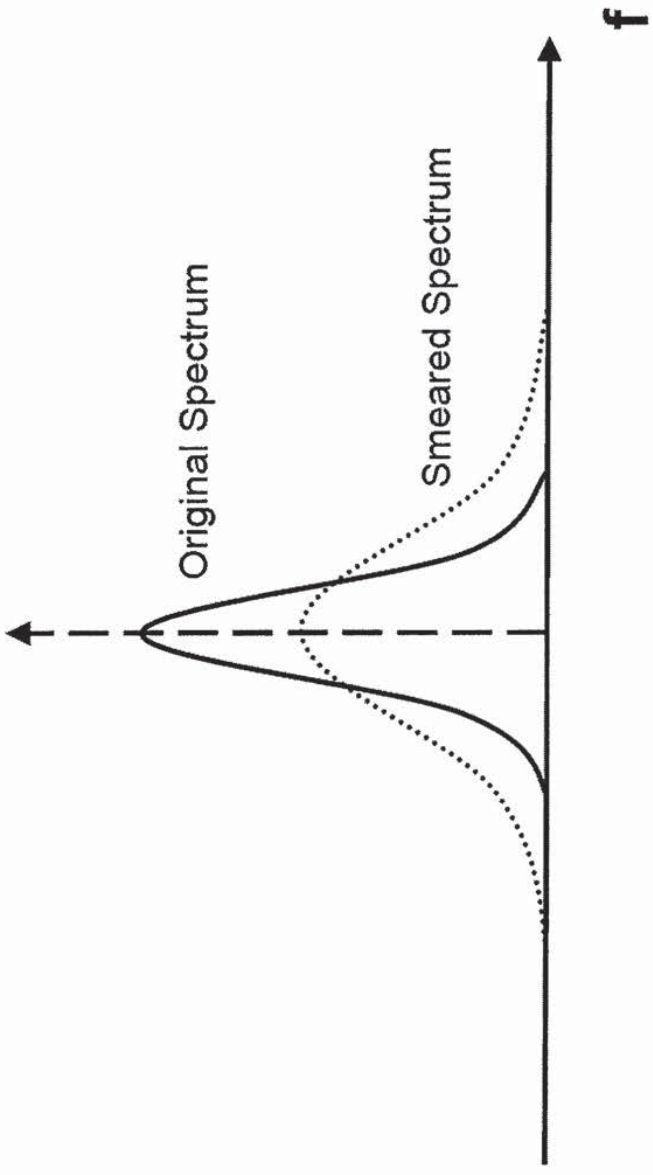


FIG. 6

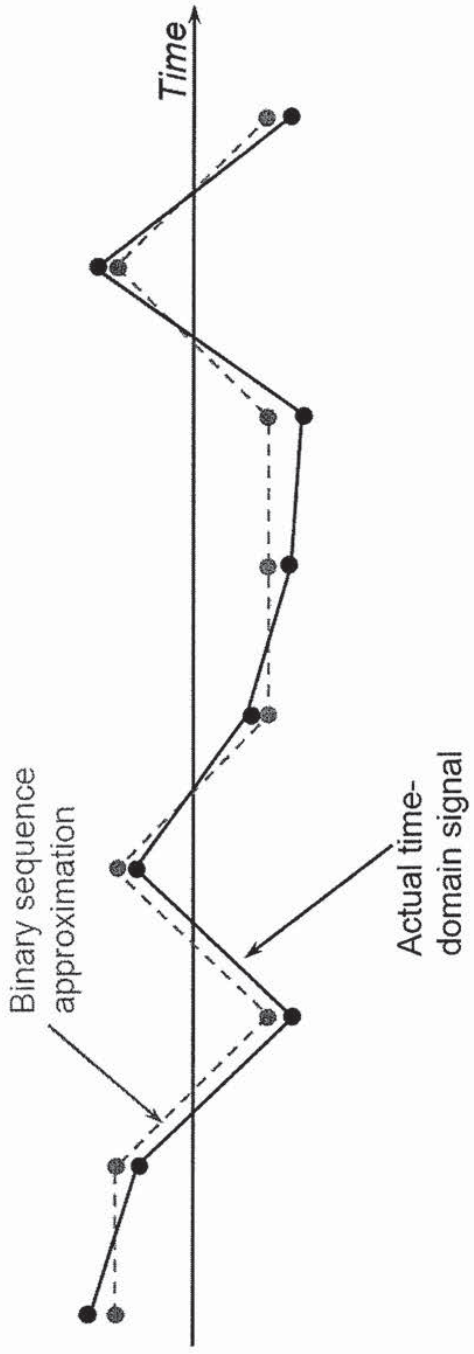

Time
Binary sequence approximation
Actual time-domain signal

FIG. 7

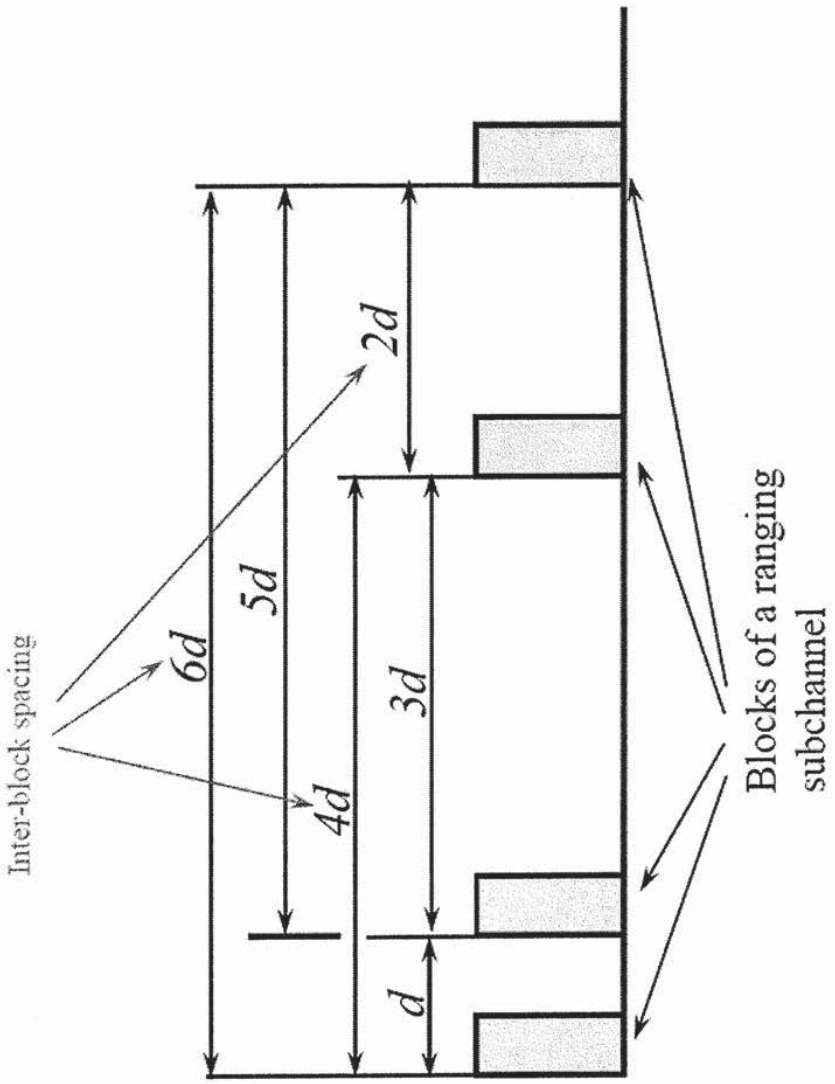

Inter-block spacing
6d
5d
4d
3d
2d
d
Blocks of a ranging subchannel

FIG. 8

METHODS AND APPARATUS FOR RANDOM ACCESS IN MULTI-CARRIER COMMUNICATION SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of U.S. patent application Ser. No. 10/583,158, entitled "METHODS AND APPARATUS FOR RANDOM ACCESS IN MULTI-CARRIER COMMUNICATION SYSTEMS", filed Aug. 27, 2008, which is a U.S. National Stage application of PCT/US05/08169, entitled "METHODS AND APPARATUS FOR RANDOM ACCESS IN MULTI-CARRIER COMMUNICATION SYSTEMS", filed Mar. 9, 2005, which claims the benefit of U.S. Provisional Patent Application No. 60/551,589, entitled "METHODS AND APPARATUS FOR RANDOM ACCESS IN MULTI-CARRIER COMMUNICATION SYSTEMS", filed Mar. 9, 2004.

BACKGROUND

In a wireless communication system, a mobile station first needs to perform a random access for establishing communication with a base station. The random access typically includes two steps: (1) Ranging and (2) Resource Request and Allocation. During Ranging, the mobile station sends a signal to the base station, so that the base station can identify the mobile station and measure the power and time delay of the mobile station, and inform the mobile station for power adjustment and time advance. During Resource Request and Allocation, the uplink and downlink resources for communication are requested and allocated. Ranging is a critical part of multi-carrier wireless communication system, and there are several important issues related to ranging:

1. The bandwidth efficiency of the ranging signals
2. The interference of ranging signal with other uplink signals
3. The detection performance and complexity at the base station receiver

The ranging process typically involves an exchange of messages between the base station and the mobile station by which the mobile station aligns itself with the start of each time slot after compensating for propagation delay and other factors. One problem in a shared medium communication network involves the ranging of many mobile stations. When many mobile stations attempt to perform the ranging simultaneously, they are forced to contend for access to the shared channel and it becomes difficult for any of the mobile stations to complete the ranging process due to the large number of collisions. As a result, the time needed for all of the mobile stations to complete the ranging process is excessive, and much bandwidth on the shared channel is wasted.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers.

FIG. **2** shows a radio resource divided into small units in both the frequency domain (subchannels) and the time domain (time slots).

FIG. **3** shows a cellular system with at least one cell and one base station.

FIG. **4** depicts a ranging subchannel composed of at least one block of subcarriers.

FIG. **5** illustrates a case of time misalignment in a ranging signal, with a base station OFDM time frame, due to uncertainty of a mobile station's round trip delay at an initial stage of random access.

FIG. **6** depicts a smeared spectrum of a subcarrier in a ranging subchannel when the ranging signal is received using a regular OFDM time frame.

FIG. **7** illustrates a ranging sequence's corresponding time-domain signal that can be approximated with a binary sequence.

FIG. **8** shows a ranging subchannel arrangement in which spacing between subcarrier blocks in the frequency domain has no, or minimum, repetition.

DETAILED DESCRIPTION

In the following description, the invention is explained with respect to some of its various embodiments, and provides specific details for a thorough understanding. However, one skilled in the art will understand that the invention may be practiced without such details. In other instances, well-known structures and functions have not been shown or described in detail to avoid obscuring aspects of the embodiments.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

The embodiments of this invention disclose methods and apparatus for random access in a multi-carrier system. In particular, ranging signals are designed to improve receiving reliability and to reduce interference with other uplink signals. Furthermore, methods and apparatus are described that improve the detection performance at the base station receiver.

In a multi-carrier communication system such as multi-carrier code division multiple access (MC-CDMA) and orthogonal frequency division multiple access (OFDMA) systems, information data are multiplexed on subcarriers that are mutually orthogonal in the frequency domain. In effect, a frequency selective channel is partitioned in frequency into a number of parallel, but small, segments that can be treated as flat fading channels and can employ simple one-tap equalizers. The modulation/demodulation can be performed using the fast Fourier transform (FFT).

In a multi-carrier communication system the physical media resource (e.g., radio or cable) can be divided in both the frequency and time domains. This canonical division provides a high flexibility and fine granularity for resource sharing. A basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers, and within a particular spectral band or channel there are a fixed number of subcarriers. There are three types of subcarriers:

1. Data subcarriers, which carry information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which

are used for assisting system functions such as estimation of system parameters; and

3. Silent subcarriers, which have no energy and are used for guard-bands and DC carriers.

The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The carriers forming one subchannel are not necessarily adjacent to each other. Each user may use part or all of the subchannels. The concept is illustrated in FIG. **1** for the interleaved subchannels at the base station transmitter. Data subcarriers can be grouped into subchannels in a particular way and the pilot subcarriers are also distributed over the entire channel in a particular way. The basic structure of a multi-carrier signal in the time domain is made up of time slots to support multiple-access. The resource division in both the frequency and time domains is depicted in FIG. **2**.

FIG. **3** illustrates a typical cellular structure. In this illustration no distinction is made between a cell and a sector. If a cell is divided into sectors, from a system engineering point of view each sector can be considered a cell. In this context, the terms "cell" and "sector" are interchangeable. Both of them are generally called a cell. In the communication system of FIG. **3** Base Station **310** is communicating with Mobile Stations **301** and **302** in Sector A of its cell site while Base Station **320** is communicating with Mobile Stations **303**, **304**, and **305** in Sector B of its cell site.

FIG. **4** illustrates two ranging subchannels, each of which is composed of multiple blocks of subcarriers. The subcarriers in each block are contiguous in frequency. FIG. **4** schematically shows that the signal power of the subcarriers towards the boundary (the lower ends and the higher ends in frequency) of a block is lower than that of the subcarriers towards the center of the block. (In a special case, the power levels of the two subcarriers at both ends of a block are set to zero.) Because different factors may cause possible overlap of two subcarrier blocks from to different transmitters, the attenuated boundary subcarriers will minimize the resulting interference.

In accordance with aspects of some embodiments, the ranging signal is carried over a ranging subchannel that contains multiple subcarriers. Either binary or non-binary signals can be modulated on the subcarriers of a ranging subchannel.

The sequence of modulating signals in a ranging subchannel is called a ranging sequence. Multiple ranging sequences are permitted in a cell. A mobile station chooses a ranging sequence for random access and uses the sequence to identify itself in the initial communication with a base station. The period of a ranging signal is called a ranging slot. A ranging slot may last over one or multiple OFDM symbols. Multiple ranging slots can be provided to increase the random access opportunity and reduce the collision probability.

In one embodiment, different cells may have different subcarrier configurations for their ranging subchannels. Different cells may also have different ranging sequence sets. These differences may be used to identify the association of a mobile station with a cell.

FIG. **5** illustrates the timing of regular uplink data signals and ranging signals (with a Guard Period G.P.). In the beginning of a random access attempt, the mobile station is unaware of its round-trip time to the base station. As a result, the arrival time of ranging signal at the base station may be misaligned with other signals which have been synchronized to the base station clock. As depicted in FIG. **5**, the random access Ranging Signal does not coincide with the expected arrival time at the base station. As shown in FIG. **6**, time misalignment of regular signals and ranging signals can cause spectrum of ranging signals to be smeared when it is received using the OFDM time window of regular signals. Therefore, misaligned subcarriers within a ranging subchannel will interfere with each other and with other data subchannels that are adjacent to them. In the following description, several methods are presented to address such problems.

In one embodiment, the ranging subchannel is composed of multiple blocks of subcarriers. The subcarriers in each block are contiguous in frequency. The signal power of the subcarriers towards the boundary (the lower ends and the higher ends in frequency) of a block is lower than that of the subcarriers towards the center of the block. In a special case, the power levels of the two subcarriers at both ends of a block are set to zero.

In yet another embodiment, each segment of a ranging sequence is a Hadamard sequence and a full ranging sequence is composed of multiple Hadamard sequences. Each segment corresponds to a block of contiguous subcarriers. In Table 1, a typical example is shown for two ranging sequences. Each segment is a 4-bit Hadamard sequence and each ranging sequence is composed of 4 segments. The two ranging sequences are segment-wise orthogonal to each other.

TABLE 1

Example of ranging sequences

Ranging Sequence 1	+1 −1 +1 −1	+1 +1 +1 +1	+1 +1 −1 −1	+1 −1 −1 +1
Ranging Sequence 2	+1 +1 +1 +1	+1 −1 −1 +1	+1 −1 +1 −1	+1 +1 −1 −1

In addition, other properties in signal processing can be exploited in sequence design. In one embodiment of the implementation, the ranging sequence is designed such that its corresponding time-domain signal exhibits relatively low peak-to-average power ratio. This improves the power efficiency of the mobile station transmission power amplifier. Furthermore, the ranging signal is designed such that the time signal can be approximated with a binary sequence (e.g., FIG. **7**), thereby reducing the complexity of the receiver correlator. While in theory, and even in practice, each modulating digit of a ranging sequence can represent a range of logic levels, a binary format is practically the simplest representation and requires the simplest receiver components for its processing. FIG. **7** illustrates a ranging sequence's corresponding time-domain signal that can be approximated with a binary sequence.

In another embodiment, the blocks of a ranging subchannel can be distributed or allocated in such a way that the autocorrelation of a ranging sequence corresponding to the ranging subchannel, in time-domain, exhibits a set of desired properties such as a narrow main peak and low sidelobes. For example, the blocks can be distributed in the frequency band of interest such that there is minimum redundancy in a co-sampling function. In other words, spacing between the blocks of a ranging subchannel in the frequency domain has no or minimum repetition, as illustrated in FIG. **8**, where the spacing consists of the set {d, 2d, 3d, 4d, 5d, 6d}.

FIG. **8** is merely an example of such possible arrangements, where an autocorrelation process only produces one major peak, regardless of the ranging sequence carried by the ranging subchannel blocks. During an autocorrelation process, two copies of a ranging signal move in parallel with respect to each other, in a step-wise manner, and at each step the sum of the multiplication of their corresponding values is computed and recorded. Note that in an interval of a ranging

subchannel where there are no subcarriers, the ranging signal value is zero. Therefore, employing the proposed arrangements, at any step except for the step during which the two copies of the ranging signal are substantially aligned, most of the non-zero values of either copy will correspond to the zero values of the other copy and the multiplication result of the corresponding values will be zero, which results in low side-lobe values.

With regard to controlling the power settings of a ranging signal, before a random access, a mobile station estimates the path loss from a base station, using the received downlink signal. It uses open-loop power control to set the power level of the ranging signal. In one embodiment, the mobile station adds a negative offset to the open-loop power setting and gradually ramps up the transmission power of the ranging signal as the number of random access failures and retrials increase.

In one embodiment, the base station receiver detects the presence of each ranging signal, its time delay, and its power level through the use of a matched filter, a correlator, or other means in the time domain, the frequency domain, or both.

In another embodiment, when the ranging subchannel is composed of blocks of contiguous subcarriers, the base station performs hierarchical detection: first in frequency domain, then in time domain. The detection process is as follows:

1. The FFT is applied to a selected window of the received time-domain signal, s(t).
2. For a particular ranging subchannel, its received version, $\{\vec{r}(k)\}_{k=1}^{K}$, is correlated in the frequency domain with the ranging sequences associated with the cell, in a segment-wise fashion, where K is the total number of blocks in a ranging subchannel. If the m^{th} sequence associated with the cell is denoted by $\{\vec{b}_m(k)\}_{k=1}^{K}$, the correlation value, P_m, is computed by:

$$P_m = \sum_{k=1}^{K} \left| \langle \vec{r}(k) \cdot \vec{b}_m(k) \rangle \right|^2,$$

where the dot-product is computed by:

$$\langle \vec{r}(k) \cdot \vec{b}_m(k) \rangle = \sum_{n=1}^{N} x(k, n) \cdot [c_m(k, n)]^*$$

and where N denotes the number of subcarriers in a block, x(k,n) denotes the received version of the n^{th} subcarrier of the k^{th} block in the given ranging subchannel, and $c_m(k,n)$ represents the value of the n^{th} subcarrier of the k^{th} block in the given ranging subchannel for the m^{th} sequence. It is noted that that both $\vec{r}(k)$ and $\vec{b}_m(k)$ are vectors of the dimension same as the segment length. If P_m is greater than a given threshold, this indicates that a ranging signal corresponding to the m^{th} sequence has been detected.

3. For the ranging signal identified in Step 2, a time-domain correlation of the full sequence of the ranging signal is performed, in a sliding-window fashion, to find the time delay of that ranging signal, that is:

$$C(\tau) = \left| \sum_{t=0}^{T} s(t+\tau) \cdot z^*(t) \right| \text{ for } \tau = 0, 1, \ldots, D$$

where T denotes the length of the time-domain ranging sequence, D corresponds to the maximum time delay allowed by the system, and z*(t) represents the time-domain signal of the detected ranging sequence. The maximum value of $C(\tau)$ for $\tau=0, 1, \ldots, D$ is the estimate of the power of the ranging signal and the corresponding value of τ indicates the time delay associated with the ranging signal.

In the case of ranging sequences composed of Hadamard sequences, the dot-products of the received signal and the ranging sequence in a particular segment in Step 2 can be evaluated simultaneously using a single Fast Hadamard Transform (FHT), thereby simultaneously detecting multiple ranging sequences.

The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

Changes can be made to the invention in light of the above "Detailed Description." While the above description details certain embodiments of the invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Therefore, implementation details may vary considerably while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.

We claim:

1. In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising:

an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and

an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and the ranging signal exhibits a low peak-to-average power ratio in the time domain; and

the ranging subchannel comprises at least one block of subcarriers within the communication channel and power levels of subcarriers at both ends of a block are set to zero.

2. The mobile station of claim 1, wherein the subcarrier configuration of the ranging subchannel for the cell is different from subcarrier configurations of ranging subchannels for other cells.

3. The mobile station of claim 1, wherein the set of ranging sequences for the cell is different from sets of ranging sequences for other cells.

4. The mobile station of claim 1, wherein subcarriers in a block are contiguous in frequency.

5. The mobile station of claim 1, further comprising an apparatus configured to control a transmission power of the ranging signal using an open-loop power control method by:

estimating a path loss between the serving base station and the mobile station based on a received downlink signal;

setting the transmission power of the ranging signal based on the path loss; and

increasing the transmission power of the ranging signal for retransmission.

6. The mobile station of claim 1, wherein a power level of subcarriers towards the high-end and low-end frequency boundaries of a block of subcarriers is lower than a power level of subcarriers towards the center of the block.

7. The mobile station of claim 1, wherein boundary subcarriers of a block of subcarriers in the ranging subchannel are attenuated to reduce interference with other uplink signals when signal time misalignment occurs at the base station.

8. The mobile station of claim 1, wherein the ranging sequence is a binary or non-binary sequence.

9. In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system, a base station configured to communicate with mobile stations in a cell via a communication channel, the base station comprising:

an apparatus configured to receive a data signal from a first mobile station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and

an apparatus configured to receive a ranging signal from a second mobile station in the cell over a ranging subchannel for random access, wherein:

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying a mobile station;

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and the ranging signal exhibits a low peak-to-average power ratio in the time domain; and

the ranging subchannel comprises at least one block of subcarriers within the communication channel and power levels of subcarriers at both ends of a block are set to zero.

10. The base station of claim 9, wherein the subcarrier configuration of the ranging subchannel for the cell is different from subcarrier configurations of ranging subchannels for other cells.

11. The base station of claim 9, wherein the set of ranging sequences for the cell is different from sets of ranging sequences for other cells.

12. The base station of claim 9, further comprising an apparatus configured to detect the ranging sequence in the received ranging signal in the time domain, frequency domain, or both time and frequency domain.

13. The base station of claim 12, wherein the apparatus applies matched filtering to the received ranging signal to detect the ranging sequence.

14. The base station of claim 12, wherein the apparatus correlates the received ranging signal with a ranging sequence stored at the base station to detect the ranging sequence.

15. The base station of claim 9, further comprising an apparatus configured to detect a time delay of the received ranging signal and to inform the second mobile station to adjust transmission time based on the detected time delay.

16. The base station of claim 9, further comprising an apparatus configured to detect a power level of the received ranging signal and to inform the second mobile station to adjust a transmission power based on the detected power level.

17. In an orthogonal frequency division multiple access (OFDMA) wireless communication system, a method for signal transmission by a mobile station to a serving base station via a communication channel, the method comprising:

transmitting a data signal over a data subchannel to the serving base station, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and

transmitting a ranging signal over a ranging subchannel to the serving base station for random access, wherein:

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences for identifying the mobile station;

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and the ranging signal exhibits a low peak-to-average power ratio in the time domain; and

the ranging subchannel comprises at least one block of subcarriers within the communication channel and power levels of subcarriers at both ends of a block are set to zero.

18. The method of claim 17, wherein a power level of subcarriers towards the high-end and low-end frequency boundaries of a block of subcarriers is lower than a power level of subcarriers towards the center of the block.

19. The method of claim 17, wherein boundary subcarriers of a block of subcarriers in the ranging subchannel are attenuated to reduce interference with other uplink signals when signal time misalignment occurs at the base station.

20. The method of claim 17, wherein subcarriers in a block are contiguous in frequency.

21. The method of claim 17, further comprising controlling a transmission power of the ranging signal using an open-loop power control method by:

estimating a path loss between the serving base station and the mobile station based on a received downlink signal;

setting the transmission power of the ranging signal based on the path loss; and

increasing the transmission power of the ranging signal for retransmission.

22. In an orthogonal frequency division multiple access (OFDMA) wireless communication system, a method for receiving signals by a base station from a plurality of mobile stations via a communication channel, the method comprising:

receiving a data signal over a data subchannel from a first mobile station, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and

receiving a ranging signal over a ranging subchannel for random access by a second mobile station, wherein:

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences for identifying the mobile station;

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and the ranging signal exhibits a low peak-to-average power ratio in the time domain; and

the ranging subchannel comprises at least one block of subcarriers within the communication channel and power levels of subcarriers at both ends of a block are set to zero.

23. The method of claim 22, further comprising detecting a time delay of the received ranging signal and informing the second mobile station to adjust transmission time based on the detected time delay.

24. The method of claim 22, further comprising detecting a power level of the received ranging signal and informing the second mobile station to adjust a transmission power based on the detected power level.

* * * * *

Exhibit 2

US010833908B2

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

(10) **Patent No.: US 10,833,908 B2**
(45) **Date of Patent: *Nov. 10, 2020**

(54) **CHANNEL PROBING SIGNAL FOR A BROADBAND COMMUNICATION SYSTEM**

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(72) Inventors: **Xiaodong Li**, Kirkland, WA (US); **Titus Lo**, Bellevue, WA (US); **Kemin Li**, Bellevue, WA (US); **Haiming Huang**, Bellevue, WA (US)

(73) Assignee: **NEO WIRELESS LLC**, Wayne, PA (US)

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

This patent is subject to a terminal disclaimer.

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(22) Filed: **Jun. 16, 2020**

(65) **Prior Publication Data**

US 2020/0313948 A1 Oct. 1, 2020

Related U.S. Application Data

(63) Continuation of application No. 15/953,950, filed on Apr. 16, 2018, now Pat. No. 10,771,302, which is a (Continued)

(51) **Int. Cl.**
H04L 12/26 (2006.01)
H04L 27/26 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 27/2626*** (2013.01); ***H04B 1/707*** (2013.01); ***H04B 1/711*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04L 12/26; H04L 5/0007; H04L 5/0028; H04L 25/03834; H04L 27/0008; H04L 27/0012
(Continued)

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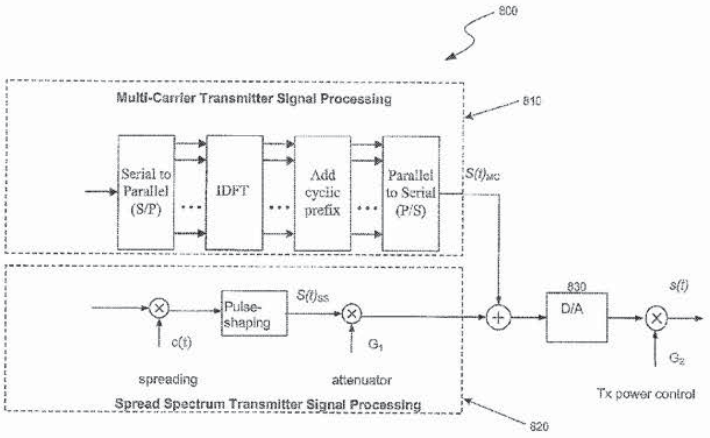
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Primary Examiner — Dmitry Levitan
(74) *Attorney, Agent, or Firm* — Volpe Koenig

(57) **ABSTRACT**

In a broadband wireless communication system, a spread spectrum signal is intentionally overlapped with an OFDM signal, in a time domain, a frequency domain, or both. The OFDM signal, which inherently has a high spectral efficiency, is used for carrying broadband data or control information. The spread spectrum signal, which is designed to have a high spread gain for overcoming severe interference, is used for facilitating system functions such as initial random access, channel probing, or short messaging. Methods and techniques are devised to ensure that the mutual interference between the overlapped signals is minimized to
(Continued)



have insignificant impact on either signal and that both signals are detectable with expected performance by a receiver.

30 Claims, 18 Drawing Sheets

Related U.S. Application Data

continuation of application No. 14/321,615, filed on Jul. 1, 2014, now Pat. No. 9,948,488, which is a continuation of application No. 13/861,942, filed on Apr. 12, 2013, now Pat. No. 8,767,522, which is a continuation of application No. 13/347,644, filed on Jan. 10, 2012, now Pat. No. 8,428,009, which is a continuation of application No. 12/975,226, filed on Dec. 21, 2010, now Pat. No. 8,094,611, which is a continuation of application No. 10/583,229, filed as application No. PCT/US2005/003518 on Jan. 27, 2005, now Pat. No. 7,864,725.

(60) Provisional application No. 60/540,586, filed on Jan. 30, 2004, provisional application No. 60/540,032, filed on Jan. 29, 2004.

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H04L 5/00	(2006.01)
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H04B 1/711	(2011.01)
H04L 25/02	(2006.01)

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

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(58) **Field of Classification Search**

USPC 370/241, 252, 310, 328, 330, 464, 532

See application file for complete search history.

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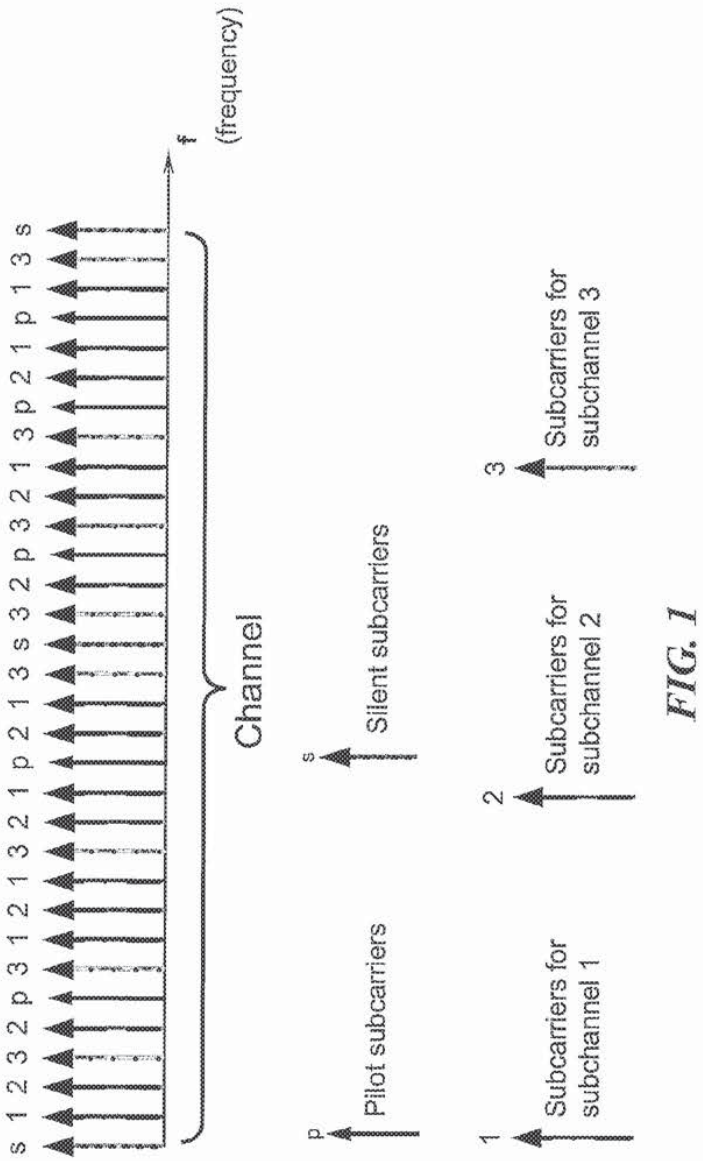

s 1 2 3 2 p 3 1 2 1 3 2 1 p 2 1 3 s 3 2 p 3 2 1 3 p 2 1 p 1 3 s
f
(frequency)
Channel
p
Pilot subcarriers
s
Silent subcarriers
1
Subcarriers for subchannel 1
2
Subcarriers for subchannel 2
3
Subcarriers for subchannel 3

FIG. 1



FIG. 2

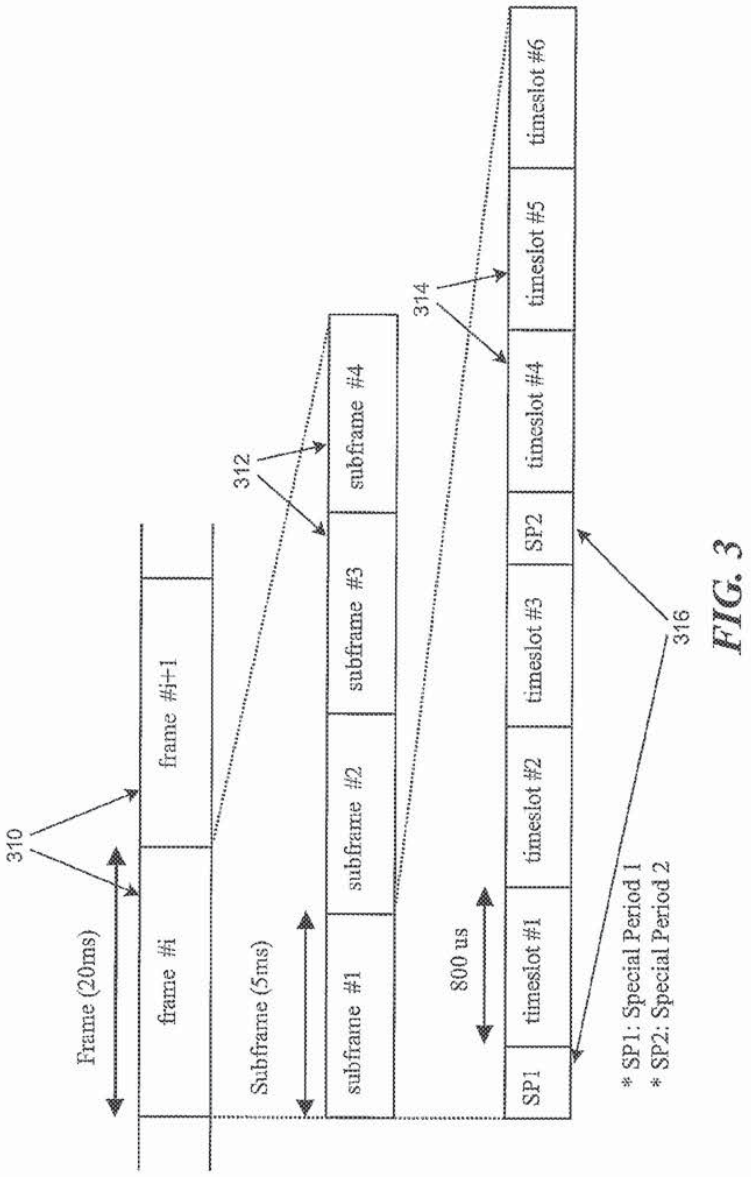

310
frame #i
frame #i+1
Frame (20ms)
312
Subframe (5ms)
subframe #1
subframe #2
subframe #3
subframe #4
800 us
314
SP1
timeslot #1
timeslot #2
timeslot #3
SP2
timeslot #4
timeslot #5
timeslot #6
316
* SP1: Special Period 1
* SP2: Special Period 2

FIG. 3

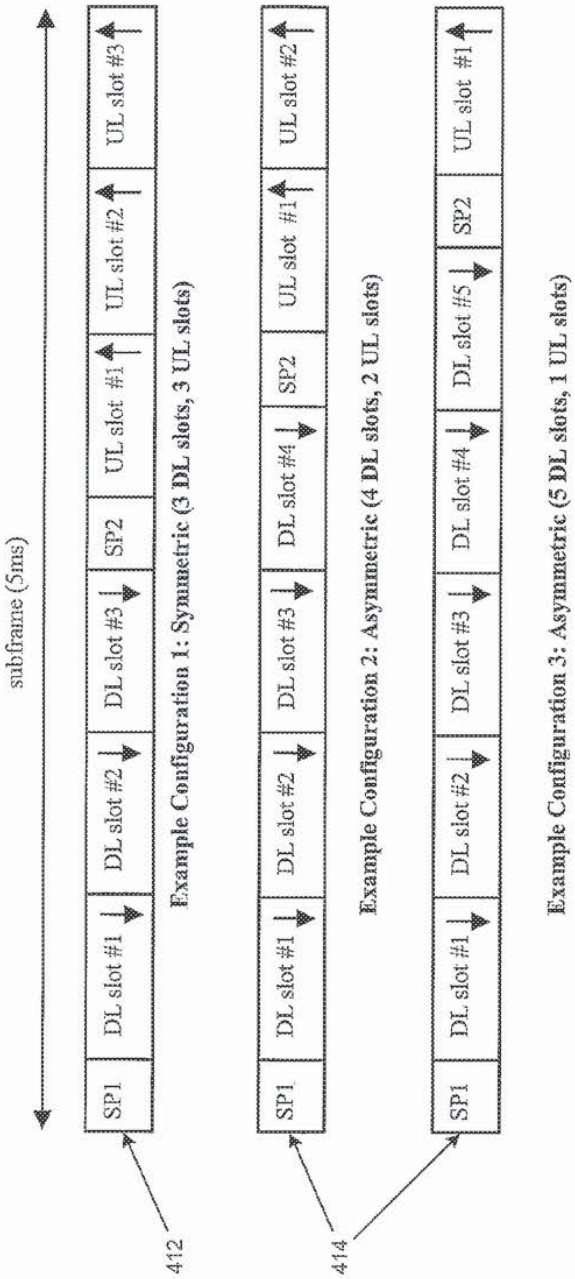

subframe (5ms)
SP1
DL slot #1
DL slot #2
DL slot #3
SP2
UL slot #1
UL slot #2
UL slot #3
Example Configuration 1: Symmetric (3 DL slots, 3 UL slots)
412
SP1
DL slot #1
DL slot #2
DL slot #3
DL slot #4
SP2
UL slot #1
UL slot #2
Example Configuration 2: Asymmetric (4 DL slots, 2 UL slots)
414
SP1
DL slot #1
DL slot #2
DL slot #3
DL slot #4
DL slot #5
SP2
UL slot #1
Example Configuration 3: Asymmetric (5 DL slots, 1 UL slots)

FIG. 4

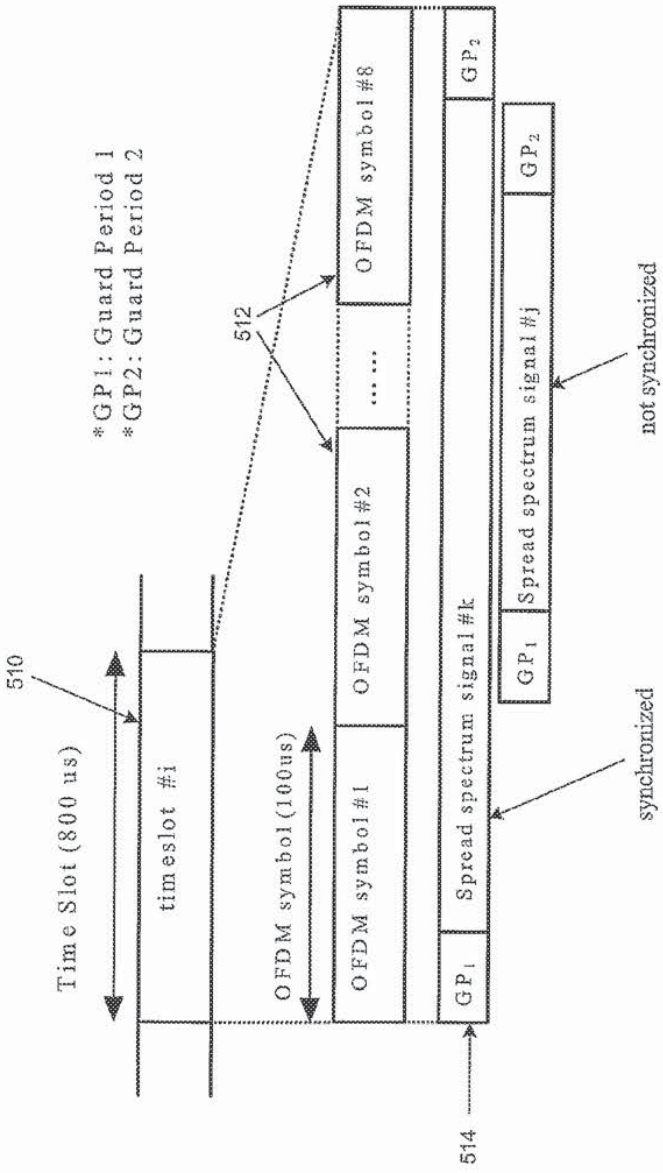

*GP1: Guard Period 1
*GP2: Guard Period 2
510
Time Slot (800 us)
timeslot #i
OFDM symbol (100us)
512
OFDM symbol#1
OFDM symbol#2
.....
OFDM symbol#8
GP1
Spread spectrum signal#k
GP2
GP1
Spread spectrum signal#j
GP2
synchronized
not synchronized
514

FIG. 5

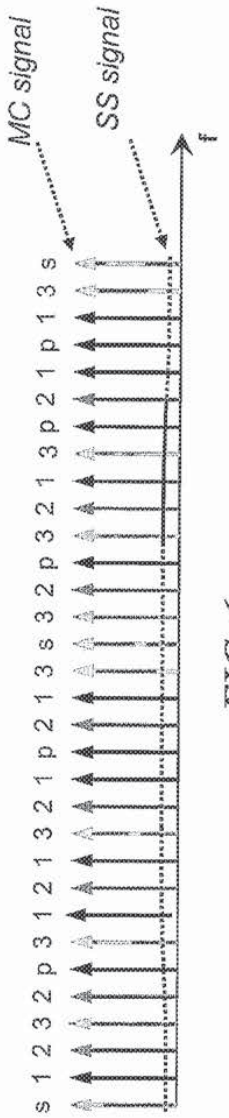


FIG. 6

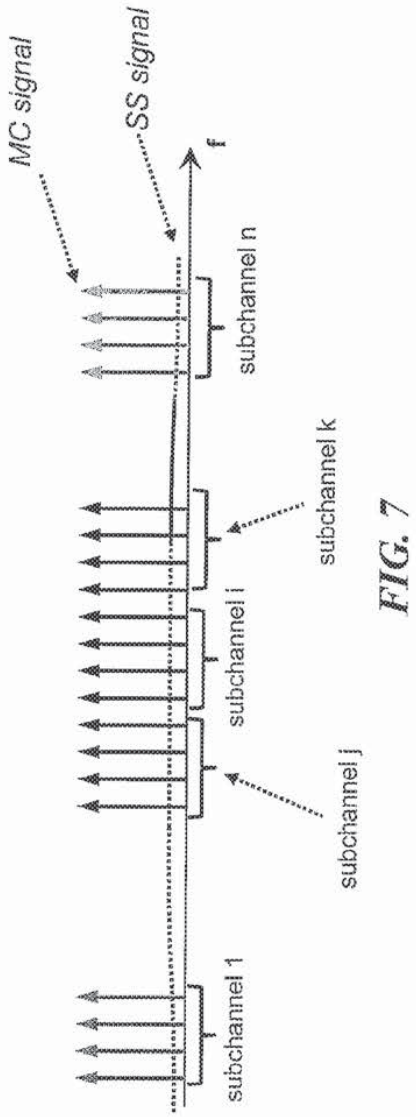

MC signal
SS signal
f
subchannel n
subchannel k
subchannel i
subchannel j
subchannel 1

FIG. 7

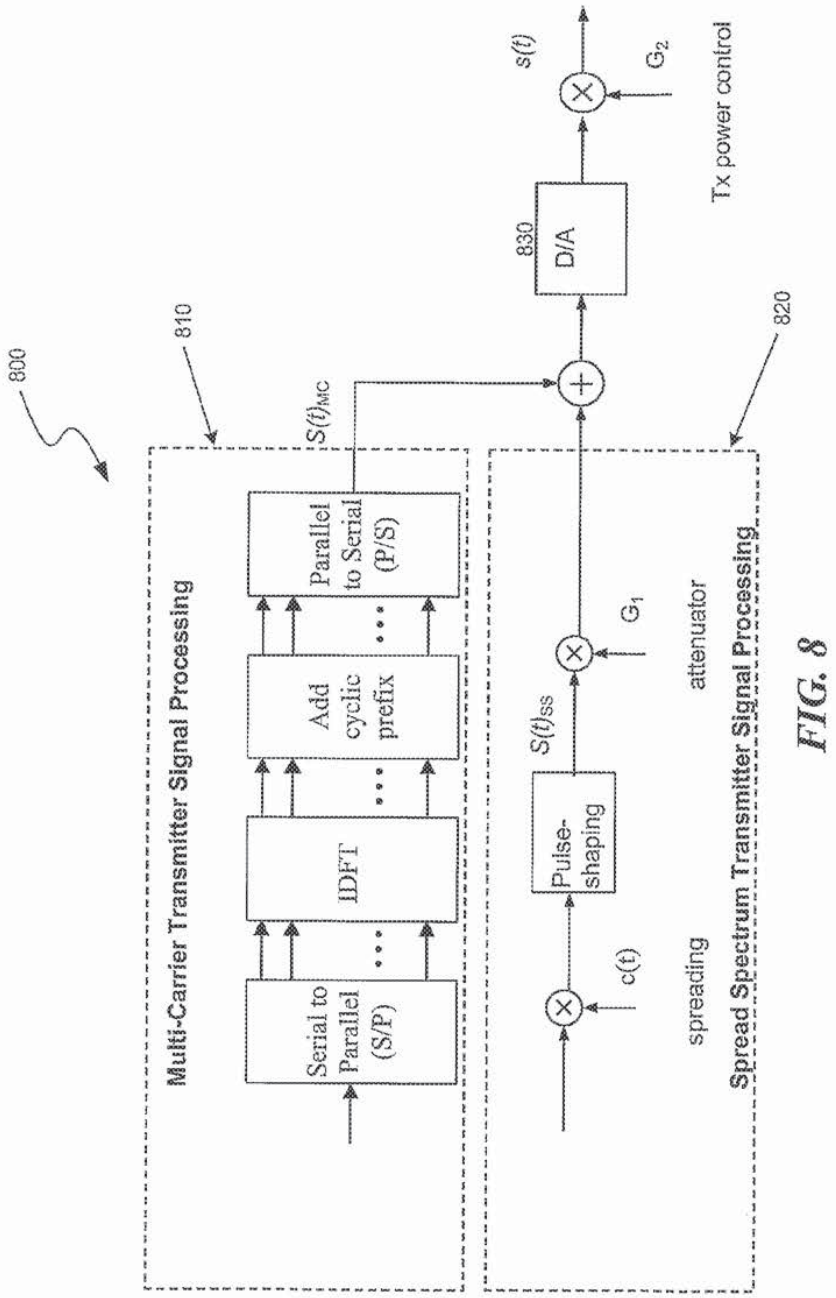

800
810
820
Multi-Carrier Transmitter Signal Processing
Spread Spectrum Transmitter Signal Processing
Serial to Parallel (S/P)
IDFT
Add cyclic prefix
Parallel to Serial (P/S)
S(t)MC
c(t)
spreading
Pulse-shaping
S(t)SS
G1
attenuator
830
D/A
s(t)
G2
Tx power control

FIG. 8

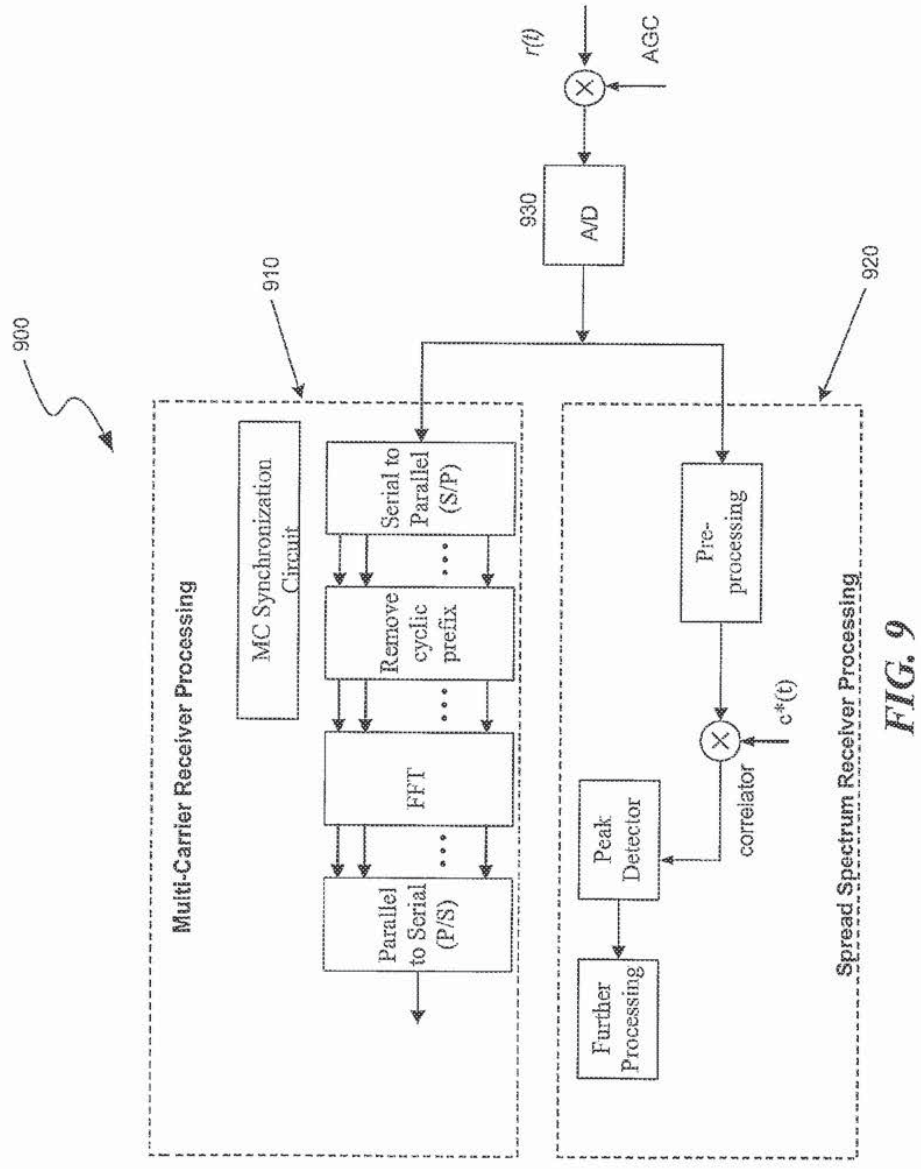

900
910
920
930
r(t)
AGC
A/D
Multi-Carrier Receiver Processing
MC Synchronization Circuit
Serial to Parallel (S/P)
Remove cyclic prefix
FFT
Parallel to Serial (P/S)
Spread Spectrum Receiver Processing
Pre-processing
c*(t)
correlator
Peak Detector
Further Processing

FIG. 9

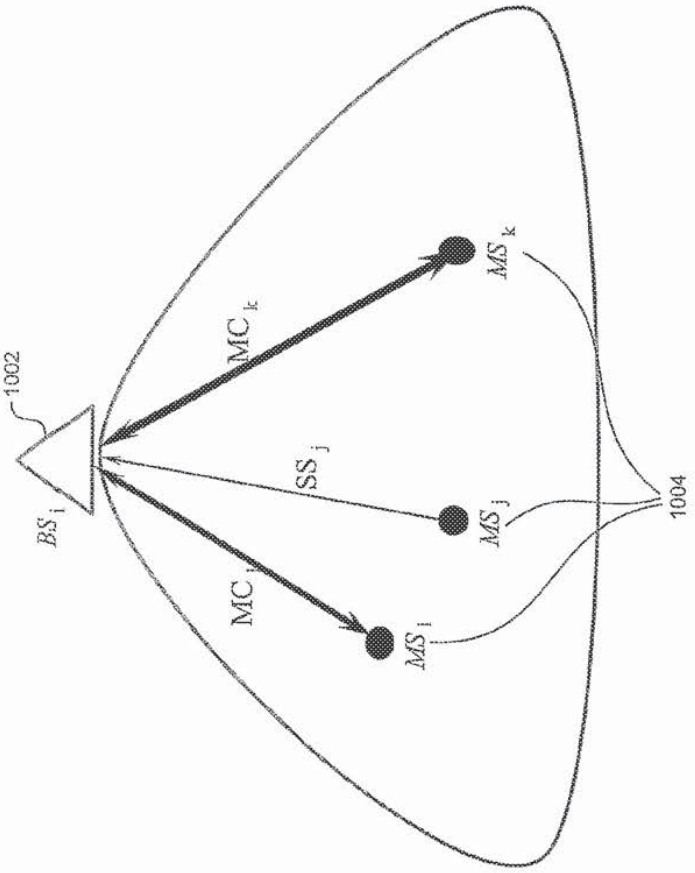


FIG. 10

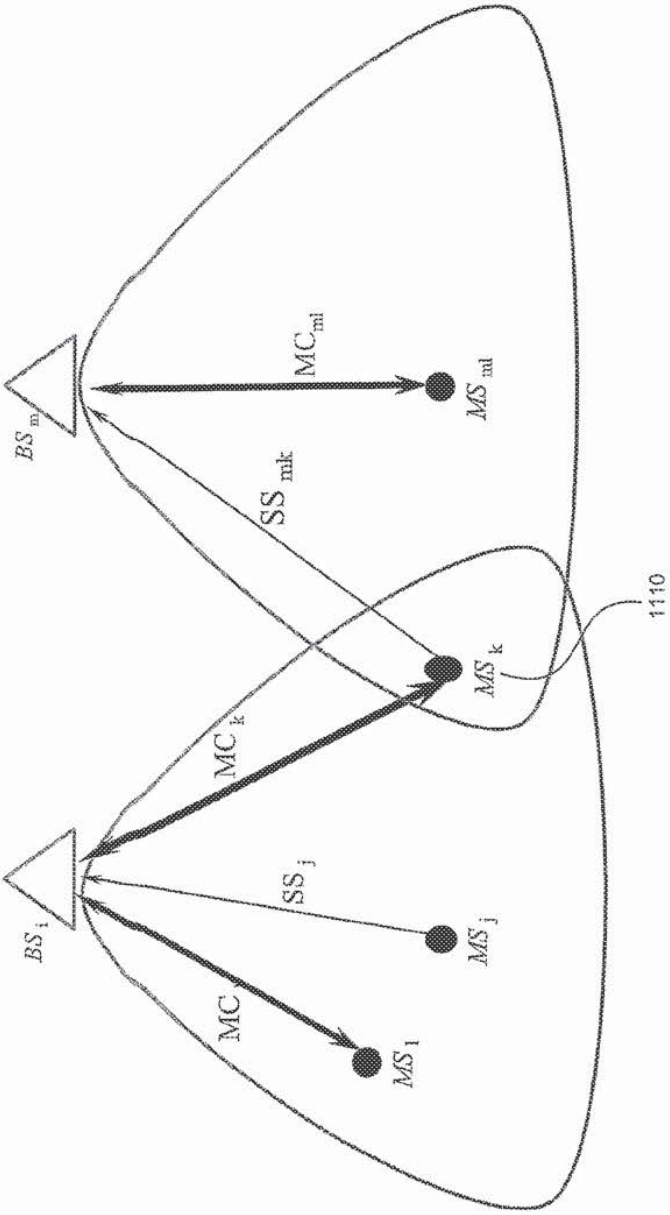


FIG. 11

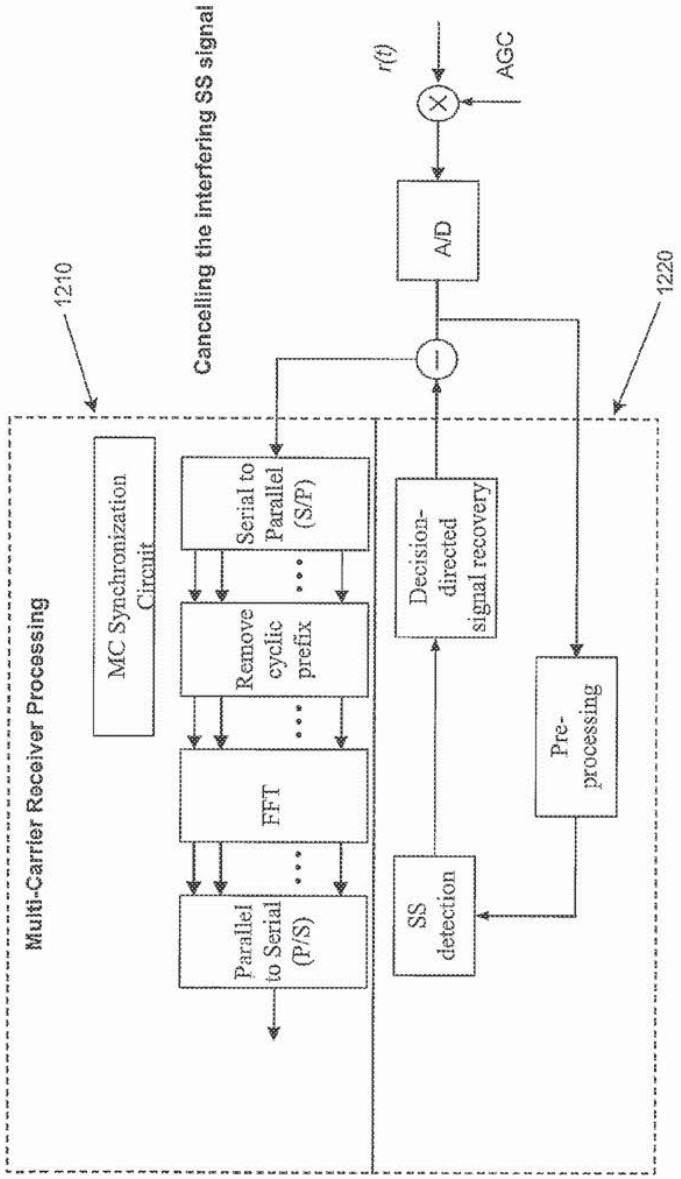

Cancelling the interfering SS signal
r(t)
AGC
A/D
1210
1220
Multi-Carrier Receiver Processing
MC Synchronization Circuit
Serial to Parallel (S/P)
Remove cyclic prefix
FFT
Parallel to Serial (P/S)
Decision-directed signal recovery
Pre-processing
SS detection

FIG. 12

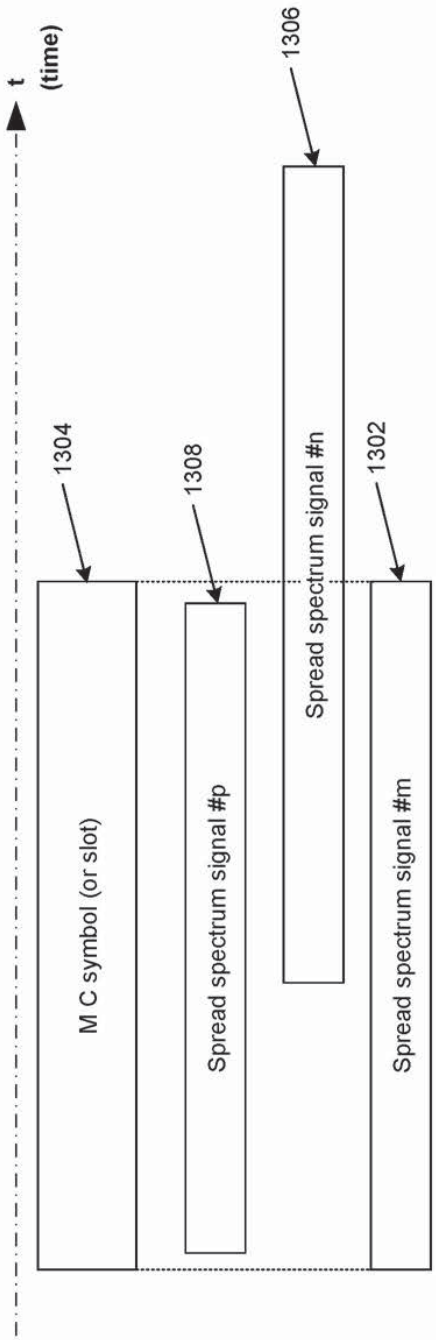

t
(time)
1306
1304
1308
1302
Spread spectrum signal #n
M C symbol (or slot)
Spread spectrum signal #p
Spread spectrum signal #m

FIG. 13

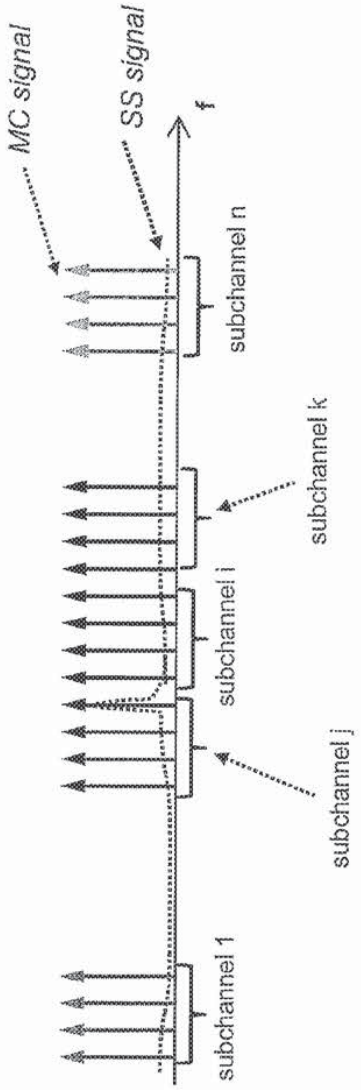

MC signal
SS signal
f
subchannel n
subchannel k
subchannel i
subchannel j
subchannel 1

FIG. 14

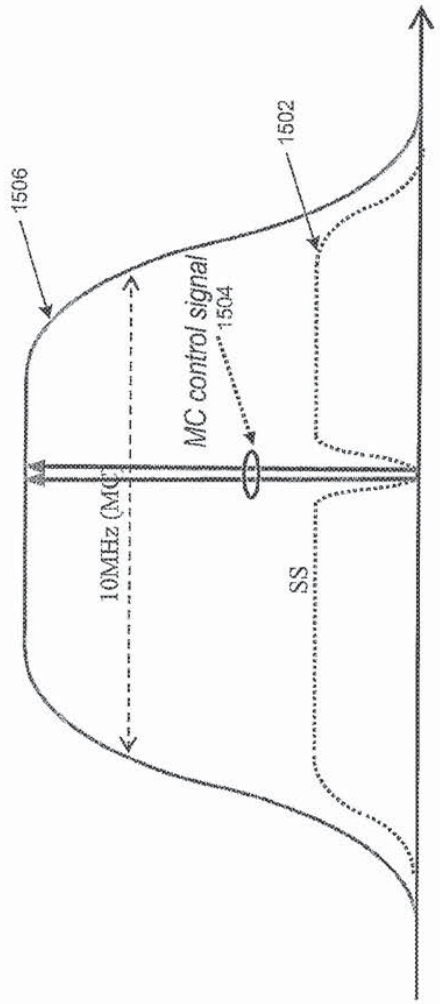


FIG. 15

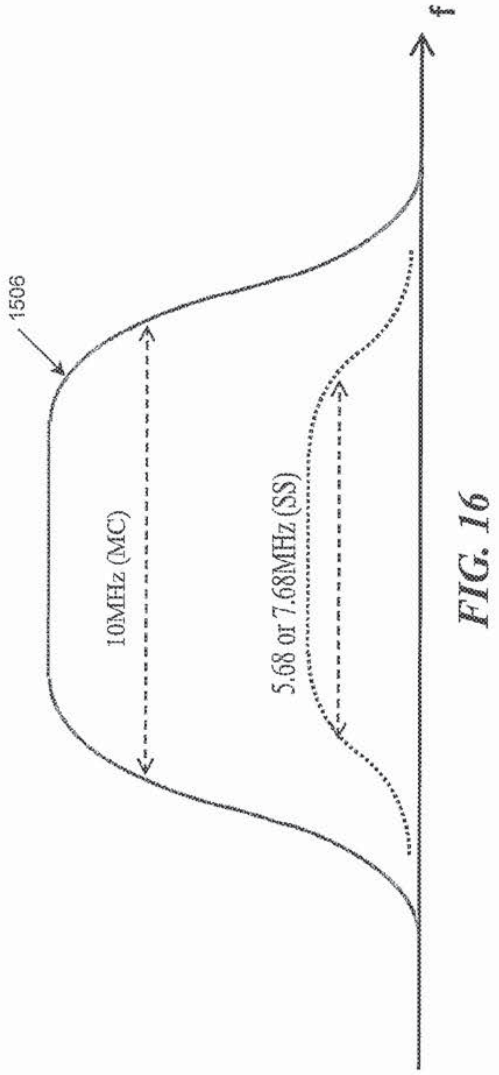


FIG. 16

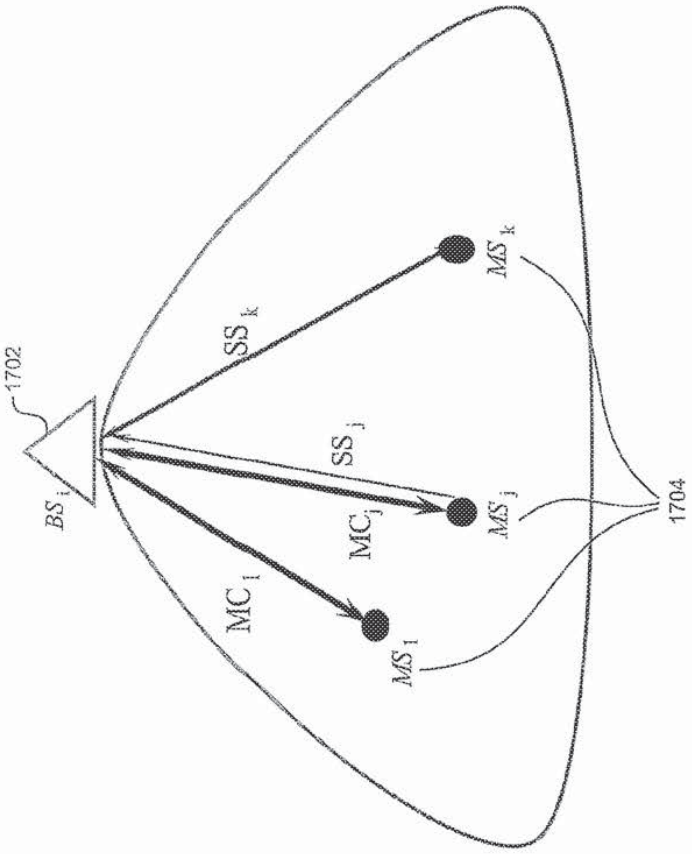


FIG. 17

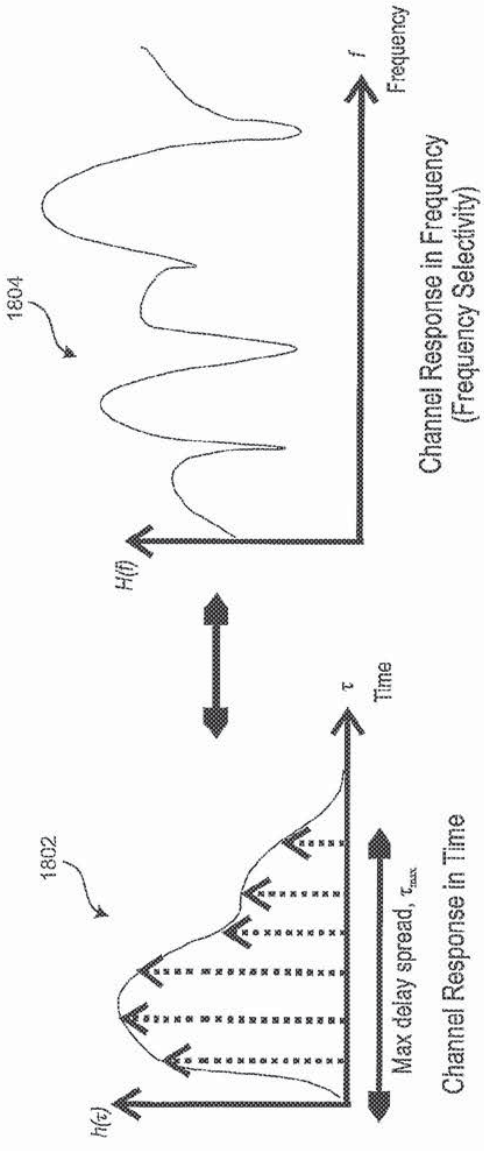

1804
H(f)
f
Frequency
Channel Response in Frequency
(Frequency Selectivity)
1802
h(τ)
τ
Time
Max delay spread, τ_{max}
Channel Response in Time

FIG. 18

CHANNEL PROBING SIGNAL FOR A BROADBAND COMMUNICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of U.S. patent application Ser. No. 15/953,950, filed Apr. 16, 2018, which is continuation of U.S. patent application Ser. No. 14/321,615, filed Jul. 1, 2014, which issued on Apr. 17, 2018 as U.S. Pat. No. 9,948,488, which is a continuation application of U.S. patent application Ser. No. 13/861,942, filed Apr. 12, 2013, which issued on Jul. 1, 2014 as U.S. Pat. No. 8,767,522, which is a continuation application of U.S. patent application Ser. No. 13/347,644, filed Jan. 10, 2012, which issued on Apr. 23, 2013 as U.S. Pat. No. 8,428,009, which is a continuation application of U.S. patent application Ser. No. 12/975,226, filed Dec. 21, 2010, which issued on Jan. 10, 2012 as U.S. Pat. No. 8,094,611, all of which are incorporated herein by reference. U.S. patent application Ser. No. 12/975,226 is a continuation application of U.S. patent application Ser. No. 10/583,229, filed Aug. 27, 2008, which issued on Jan. 4, 2011 as U.S. Pat. No. 7,864,725, which is the National Stage Application of International Application No. PCT/US2005/003518, filed Jan. 27, 2005, which claims the benefit of U.S. Provisional Patent Application No. 60/540,586, filed on Jan. 30, 2004, and of U.S. Provisional Patent Application No. 60/540,032, filed on Jan. 29, 2004.

BACKGROUND

A direct Sequence Spread Spectrum (DSSS) system is inherently capable of supporting multi-cell and multi-user access applications through the use of orthogonal spreading codes. The initial access of the physical channel and frequency planning are relatively easier because of interference averaging in a DSSS system. It has been widely used in some existing wireless networks. However, a DSSS system using orthogonal spreading codes, may suffer severely from the loss of orthogonally in a broadband environment due to multi-path propagation effects, which results in low spectral efficiency.

In broadband wireless communications, Multi-Carrier (MC) technology is drawing more and more attention because of its capability. An MC system such as an Orthogonal Frequency Division Multiplexing (OFDM) system is capable of supporting broadband applications with higher spectral efficiency. An MC system mitigates the adverse effects of multi-path propagation in wireless environments by using cyclic prefixes to extend the signal period as the data is multiplexed on orthogonal sub-carriers. In effect, it converts a frequency selective channel into a number of parallel flat fading channels which can be easily equalized with simple one-tap equalizers. The modulator and the demodulator can be executed efficiently via the fast Fourier transform (FFT) with much lower cost. However, MC systems are vulnerable while operating in multi-user and multi-cell environments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers.

FIG. **2** illustrates a radio resource being divided into small units in both frequency and time domains.

FIG. **3** illustrates a frame structure of an exemplary OFDM system.

FIG. **4** illustrates three examples of a subframe structure in the exemplary OFDM system.

FIG. **5** illustrates slot structure of the OFDM system and the overlay system.

FIG. **6** is an illustration of MC signals overlaid with DSSS signals in the frequency domain where the power level of the DSSS signal is much lower than that of the MC signal.

FIG. **7** is same as FIG. **6** wherein not all MC subchannels are occupied.

FIG. **8** illustrates a transmitter structure of MC and DSSS overlay system.

FIG. **9** illustrates a receiver structure of MC and DSSS overlay system.

FIG. **10** illustrates examples of communications between a base station and multiple mobile stations transmitting DSSS and MC signals.

FIG. **11** illustrates a mobile station sending DSSS signals to its current serving base station, or other base stations.

FIG. **12** illustrates using interference cancellation technique to cancel interfering DSSS signal in a composite signal to obtain a clearer MC signal.

FIG. **13** illustrates a DSSS signal and a MC signal fully overlaid or partially overlaid at MC symbol or slot boundary in time domain.

FIG. **14** illustrates a DSSS signal with a high Peak to Average Ratio in frequency domain causing strong interference to certain MC subcarriers.

FIG. **15** illustrates using spectrum nulls in DSSS signal to protect an MC control subchannel.

FIG. **16** illustrates spectrum control for DSSS signal using simple sub-sampling method.

FIG. **17** illustrates examples of communications between a base station and multiple mobile stations transmitting both DSSS and MC signals.

FIG. **18** illustrates a typical channel response in the time and frequency domains. By estimating the peaks of a channel response in the time domain, the channel profile in the frequency domain can be obtained.

DETAILED DESCRIPTION

A broadband wireless communication system where both the Multi-Carrier (MC) and direct Sequence Spread Spectrum (DSSS) signals are intentionally overlaid together in both time and frequency domains is described. The system takes advantage of both MC and DSSS techniques to mitigate their weaknesses. The MC signal is used to carry broadband data signal for its high spectral efficiency, while the DSSS signal is used for special purpose processing, such as initial random access, channel probing, and short messaging, in which signal properties such as simplicity, self synchronization, and performance under severe interference are of concern. In the embodiments of this invention both the MC and the DSSS signals are distinguishable in normal operations and the interference between the overlaid signals is insufficient to degrade the expected performance of either signal.

Unlike a typical CDMA system where the signals are designed to be orthogonal in the code domain or an OFDM system where the signals are designed to be orthogonal in frequency domain, the embodiments of this invention overlay the MC signal, which is transmitted without or with very low spreading, and the DSSS signal, which is transmitted at a power level lower than that of the MC signal.

In accordance with aspects of certain embodiments of this invention, the MC signal is modulated on subcarriers in the frequency domain while the DSSS signal is modulated by

the information bits or symbols in the time domain. In some cases the information bits modulating the DSSS sequence are always one.

This invention further provides apparatus and means to implement the mentioned processes and methods in a broadband wireless multi-access and/or multi-cell network, using advanced techniques such as transmit power control, spreading signal design, and iterative cancellation.

The mentioned MC system can be of any special format such as OFDM or Multi-Carrier Code Division Multiple Access (MC-CDMA). The presented methods and apparatus can be applied to downlink, uplink, or both, where the duplexing technique can be either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

Various embodiments of the invention are described to provide specific details for thorough understanding and enablement; however, the aspects of the invention may be practiced without such details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the essential matters.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

MULTI-CARRIER COMMUNICATION SYSTEM

The physical media resource (e.g., radio or cable) in a multi-carrier communication system can be divided in both the frequency and time domains. This canonical division provides a high flexibility and fine granularity for resource sharing.

The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. Within a particular spectral band or channel, there are a fixed number of subcarriers. There are three types of subcarriers:

1. Data subcarriers, which contain information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are employed for assisting system functions such as estimation of system parameters; and
3. Silent subcarriers, which have no energy and are used for guard bands and DC carrier.

FIG. **1** illustrates a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers. The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The carriers forming one subchannel are not necessarily adjacent to each other. As depicted in FIG. **1**, each user may use part or all of the subchannels.

FIG. **2** illustrates a radio resource being divided into small units in both frequency (subchannels) and time domains (time slots). The basic structure of an MC signal in the time domain is made up of time slots to support multiple-access.

AN EXEMPLARY MC SYSTEM

An OFDM system is used in the system as a special case of an MC system. The system parameters for the uplink under consideration are listed in Table 1. FIG. **3** illustrates a frame structure of a suitable OFDM system. In this system, a 20 ms frame **310** is divided into four 5 ms subframes **312**. One subframe **312** consists of six time slots **314** and two special periods **316**, which serve transition time from downlink to uplink and vise versa. The six time slots in one subframe can be configured as either uplink or downlink slots symmetrically or asymmetrically.

FIG. **4** illustrates three examples of a subframe structure in an OFDM system: one symmetric configuration **412** and two asymmetric configurations **414**, each with differing number of uplink (UL) and downlink (DL) slots. FIG. **5** illustrates a slot structure of an OFDM system and an overlay system. One 800 μs time slot **510** is comprised of 8 OFDM symbols **512**, which are overlaid by DSSS signals **514** in the time domain. Two guard periods GP**1** and GP**2** are allocated for the DSSS signal **514**.

TABLE 1

Uplink system parameters	
Data Rate	2, 4, 8, 16, 24 Mbps
Modulation	QPSK, 16-QAM
Coding rate	1/8, 1/4, 1/2, 3/4
IFFT/FFT size	1024
OFDM symbol duration	100 us
Guard interval	11.11 us
Subcarrier spacing	9.765625 kHz
System sampling rate (fs)	11.52 MHz
Channel spacing	10 MHz

DETAILED DESCRIPTION OF A MC AND DSSS OVERLAY SYSTEM

FIG. **5** illustrates the overlay of the MC and DSSS signals, where the DSSS signal overlaps with the MC signal in the time domain. The overlaid signal can be aligned at the boundary of MC slot or MC symbol when they are synchronized (for example, DSSS signal #k in FIG. **5**). It can also be not aligned when they are not synchronized (for example, DSSS signal #j in FIG. **5**). In one embodiment, the DSSS signal is placed at the period of cyclic prefix of the OFDM symbol.

FIG. **6** is an illustration of MC signals overlaid with DSSS signals in the frequency domain where the power level of the DSSS signal is much lower than that of the MC signal. The subcarriers in a subchannel are not necessarily adjacent to each other in the frequency domain. FIG. **7** is similar to FIG. **6** wherein not all MC subchannels are occupied. It illustrates a scenario where some MC subchannels are not energized.

In another embodiment, the MC signal is modulated on subcarriers in the frequency domain while the DSSS signal is modulated in either the time domain or the frequency domain. In one embodiment the modulation symbol on the DSSS sequence is one and the sequence is unmodulated.

FIG. **8** illustrates a transmitter structure **800** of an MC and DSSS overlay system, wherein the MC signal and DSSS signal are added together prior to Digital to Analog (D/A) conversion **830**. In FIG. **8**, the top branch **810** is an OFDM transmitter and the bottom branch **820** is the spread spec-

trum transmitter. In the MC transmitter, the S/P buffer converts the sequential inputs into parallel outputs, which are in turn inputted to the inverse discrete Fourier transform (IDFT). The outputs from the IDFT are the time domain signals, which are converted from parallel to sequential signals after a cyclic prefix is added. Adding the prefix can also be performed after the P/S conversion. In the spread spectrum transmitter, the DSSS sequence is modulated by the information bits or symbols and the modulated signals will undergo pulse-shaping filtering so that the signal spectrum meets specified criteria.

A digital attenuator (G**1**) is used for the DSSS signal to adjust its transmitted signal level relative to the MC signal. The two signals are overlaid in the digital domain before converting to a composite analog signal. A second analog variable gain (G**2**) is used subsequent to the D/A converter **830** to further control the power level of the transmitted signal. When the MC signal is not present, both G**1** and G**2** will be applied to the DSSS signal to provide sufficient transmission dynamic range. G**2** can be realized in multiple circuit stages.

FIG. **9** illustrates a receiver structure **900** of an MC and DSSS overlay system. A composite signal is processed by a MC receiver **910** and DSSS receiver **920**. At the receiver side, after automatic gain control (AGC), an Analog-to-Digital (ND) converter **930** converts the received analog signal to digital signal. The MC receiver basically performs a reverse process of the MC transmitter. The MC synchronization circuit carries out the synchronization in both time and frequency for the receiver to function properly. The outputs of the P/S are information bits or symbols. To detect whether a DSSS signal is present, the signal is despread with a matched filter or a correlator, using the access sequence, to check if the correlation peak exceeds a predefined threshold. The information from the DSSS receiver **920** will then be used to decode the mobile station's signature in the case of initial random access; to derive the channel information in the case of channel probing; or to decode the information bit in the case of short messaging.

In one embodiment a rake receiver is used in the DSSS receiver **920** to improve its performance in a multi-path environment. In another embodiment, the MC signal is processed as if no DSSS signal is present. In yet another embodiment, advanced interference cancellation techniques can be applied to the composite signal to cancel the DSSS signal from the composite signal thus maintaining almost the same MC performance.

The transmitted composite signal for user i can be represented by:

$$s_i(t)=G_{i,2}*[G_{i,1}*s_{i,SS}(t)++b_i*s_{i,MC}(t)] \quad (1)$$

where M is 0 when there is no MC signal and is 1 when an MC signal is present. Similarly, $G_{i,1}$ is 0 when there is no DSSS signal and varies depending on the power setting of the DSSS signal relative to the MC signal when a DSSS signal is present. $G_{i,2}$ is used to control the total transmission power for user i. The received signal can be represented by:

$$r(t) = \sum_{i=1}^{M} s_i(t) + N + I \quad (2)$$

where M is the total number of mobile station actively communicating with the current base station, N is the Gaussian noise, and I is the total interference from all the mobile stations in current and other base stations.

Denoting the received power of the MC signal as P_{MC} and the received power of the DSSS signal as P_{SS}, the signal to interference and noise ratio (SINR) for the MC signal is:

$$SINR_{MC}=P_{MC}/(N+1) \quad (3)$$

when the DSSS signal is not present; and is

$$SINR'_{MC}=P_{MC}/(N+I+P_{SS}) \quad (4)$$

when the DSSS signal is present. The system is designed such that the $SINR'_{MC}$ meets the SINR requirement for the MC signal and its performance is not compromised in spite of interference from the overlaid DSSS signal.

In one embodiment, the DSSS signal is power controlled such that P_{SS} is well below the noise level, N.

On the other hand, the SINR for the DSSS signal is

$$SINR_{SS}=P_{SS}/(N+I+P_{MC}) \quad (5)$$

Denoting the spreading factor for the DSSS signal as K_{SF}, the effective SINR for one symbol after despreading is:

$$SINR'_{SS}=P_{SS}*K_{SF}/(N+I+P_{MC}) \quad (6)$$

$SINR'_{SS}$ must be high enough to meet the performance requirement when detecting or decoding the information conveyed in the DSSS signal. In one embodiment, K_{SF} is chosen to be 1000, so that the DSSS signal is boosted with 30 dB spreading gain after despreading.

FIG. **11** illustrates a mobile station **1110** sending DSSS signals to its current serving base station or other base stations. The latter case is especially helpful in hand-off processes. In this Figure, a mobile station MS_k is communicating with a BS_i using an MC signal while transmitting a DSSS signal to BS_k.

POWER CONTROL

As discussed above, one design issue is to minimize the power of the DSSS signal to reduce its interference with the MC data signal. In one embodiment, the initial power setting of a mobile station, T_{MS_tx} (in dBm), is set based on path loss, L_{path} (in dB), and the desired received power level at the base station, $P_{BS\_rx\_des}$ (in dBm),

$$T_{MS\_tx}=P_{BS\_rx\_des}+L_{path}-C_1-C_2 \quad (7)$$

C_1 (in dB) is set to a proper value so that the SINR of the MC as specified in equation (4) meets its requirement. C_2 (in dB) is an adjustment to compensate for the power control inaccuracy. Open loop power control inaccuracy is mainly caused by a discrepancy between an estimated path loss by the mobile station and the actual path loss.

In one embodiment, C_1 is set to 9 dB for MC using QPSK modulation with ½ error control coding or 15 dB for MC using 16 QAM modulation with ½ error control coding. C_2 is set to 10 dB or 2 dB depending on whether the mobile station is under open loop power control or closed loop power control. Power control for the DSSS signal also eases the spectrum mask requirement for the DSSS signal because the DSSS signal level is much lower than that of the MC signal.

With total power offset of C_1+C_2 subtracted from an initial transmission power of the DSSS signal, the spreading factor of the DSSS signal needs to be set high enough (e.g., 512 (27 dB) or higher) so that the DSSS signal can be detected in normal conditions. This requires a sufficient number of bits of the A/D converter at the base station, for example, 12 bits.

In one embodiment, the D/A converter at the mobile station uses 12 bits, among which 8 bits are targeted for the MC signal (assuming 3 bits are reserved for MC peak to

average consideration). Thus, there are enough bits left for the DSSS signal even with significant attenuation relative to the MC signal.

CANCELING THE INTERFERENCE OF DSSS SUGNAL TO THE MC SIGNAL

In one embodiment, the base station employs interference cancellation techniques to cancel the DSSS interference to the MC signal. FIG. **12** illustrates a system for using an interference cancellation technique to cancel an interfering DSSS signal in a composite signal to obtain a clearer MC signal. First, a DSSS signal is detected by the DSSS receiver **1220**; then it is subtracted (decision directed) from the total received signal to obtain a cleaner MC data signal in the MC receiver **1210**, as illustrated in FIG. **12**. In another embodiment, multiple step iterative cancellation can be applied to further improve the effectiveness of the interference cancellation. The MC receiver basically performs a reverse process of the MC transmitter mentioned above. The MC synchronization circuit carries out the synchronization in both time and frequency for the receiver to function properly. The outputs of the P/S are information bits or symbols.

DSSS SIGNAL DESIGN

DSSS sequences are chosen to have good autocorrelation and cross-correlation properties (i.e., with high peak to sidelobe ratio). In one embodiment, pulse-shaping is applied to restrict the spectrum mask of DSSS signals and to reduce impacts on the MC signals in the frequency domain. For example, the transmitter pulse-shaping filter applied to the DSSS signal can be a root-raised cosine (RRC) with roll-off factor α in the frequency domain. The impulse response of the chip impulse filter $RC_0(t)$ is

$$RC_0(t) = \frac{\sin\left(\pi \frac{t}{T_C}(1-\alpha)\right) + 4\alpha \frac{t}{T_C}\cos\left(\pi \frac{t}{T_C}(1+\alpha)\right)}{\pi \frac{t}{T_C}\left(1-\left(4\alpha \frac{t}{T_C}\right)^2\right)} \quad (8)$$

where T_c is the chip duration.

FIG. **13** illustrates a DSSS signal and a MC signal fully overlaid or partially overlaid with an MC symbol or slot boundary in the time domain. The DSSS and the MC signals may be aligned at the symbol (or slot) boundary when they are synchronized, or partially overlapped in the time domain when they are not synchronized, as shown in FIG. **13**, where a DSSS signal #m **1302** fully overlaps with a MC symbol (or slot) **1304** in time domain, while a DSSS signal #n **1306** overlaps with the MC symbol (or slot) only partially.

FIG. **14** illustrates a DSSS signal with a high Peak to Average Ratio in the frequency domain causing strong interference to certain MC subcarriers. The sequence used to spread the DSSS signal has to be designed to avoid cases where the DSSS signal may have a high Peak to Average ratio (PAR) in the frequency domain and its spikes may cause severe interference with some MC subcarriers, as illustrated in FIG. **14**. In one embodiment, the DSSS sequence is designed so that, in partial or in full, it has low PAR in the frequency domain using signal processing techniques, such as a PAR reduction algorithm. Either binary or non binary sequences can be used.

In another embodiment, Golay complementary sequences, Reed-Muller codes, or the codes designed with similar construction methods may be used to control the PAR of DSSS sequences in the frequency domain, thereby limiting the interference of DSSS signals to MC signals, which are demodulated in the frequency domain. In one embodiment, guard periods are added to the DSSS signal which overlaps with one MC symbol, as shown by DSSS signal #p **1308** in FIG. **13**. The guard periods ensure that a well-designed DSSS sequence (with low PAR in frequency domain) causes little interference with the MC subcarriers even when there is time misalignment in a DSSS signal relative to the OFDM symbol period.

Within MC subcarriers, the control subcarriers are more important than the data subcarriers and may need to have a better protection in the overlay system.

FIG. **15** illustrates using spectrum nulls in the DSSS signal **1502** to protect an MC control subchannel. In one embodiment, the DSSS sequence is designed to have spectrum nulls at MC control subchannels to avoid excess interference with the uplink MC control signals **1504**, as illustrated in FIG. **15**. One such scheme is to use subsampling such that the chip rate of the DSSS signal is ½ or ⅔ of the system sampling rate, which means the DSSS spectrum will only occupy the center portion with a width of 5.76 MHz or 7.68 MHz out of the 10 MHz available spectrum **1506**, as shown in FIG. **16**. Its interference with the MC sub-carriers over the rest of the spectrum will be much lower where the MC subchannels, carrying control information or using higher modulation subcarriers (such as 16 QAM), are placed.

INITIAL RANDOM ACCESS USING THE OVERLAY SCHEME

FIG. **10** illustrates a DSSS signal used as initial random access by the mobile station MS_j **1004**, in an overlay system. In the mean time, MS_i and MS_k are transmitting MC signals to the base station BS_i **1002**. In one embodiment of the invention, the DSSS signal is used for initial random access and the MC signal is used by multiple mobile stations to transmit high rate data and related control information, as illustrated in FIG. **10**. In this arrangement the mobile station MS_j is transmitting its initial access DSSS signal simultaneously with the MC signals from other mobile stations (in this case, MS_i and MS_K) to the base station BS_i.

In the initial random access of a multi-carrier multiple access system, a mobile station cannot transmit directly onto the control subchannel because its transmission time and power have not been aligned with other mobile stations. When this mobile station powers up or wakes up from a sleep mode, it first listens to a base station broadcasting channel and finds an available random access DSSS channel. It then sends an initial random access signal over the DSSS channel with a certain signature code or sequence that is designated to the corresponding base station and is broadcasted to all the mobile stations by each base station.

The initial access DSSS signal arrives at the base station together with MC signals from other mobile stations, each carrying data and control information. The initial power level of the DSSS signal is based on the open power loop control settings. A sufficient guard period is reserved in the DSSS signal to account for initial time alignment uncertainty, as shown in FIG. **5**.

If the base station successfully detects the DSSS signal, it sends the acknowledgement (ACK) carrying information such as a signature or other unique mobile station identifier and power and time adjustments of the mobile on the downlink control channel in the next available timeslot. The

mobile station whose transmission signature matches that of the acknowledgement then moves to the designated uplink MC control channel using the assigned time and power values and further completes the message transmission.

If no feedback is received at the mobile station after a pre-defined number of slots, it assumes that the access slot was not detected by the base station, and will ramp up the transmission power of the DSSS signal by one step and re-transmit it, until it reaches the maximum allowable transmit signal power or the maximum retry times. In one embodiment, the power ramping step of the mobile station is set to be 1 dB or 2 dB which is configured by the base station on the downlink broadcasting channel. The maximum allowable transmit signal power and the retry times are also controlled by the base station depending on the uplink modulation/coding scheme and available access channels. During the initial random access, the DSSS signal can also be used for channel probing and short messaging.

CHANNEL PROBING USING DSSS IN THE OVERLAY SYSTEM

In one embodiment of the invention, the DSSS signal is used to assist estimation of channel characteristics. In this case, the mobile station is already synchronized in time and frequency with the base station, and its transmission of the MC signal is under closed-loop power control with the base station.

FIG. **17** illustrates examples of communications between a base station **1702** and multiple mobile stations **1704** transmitting both DSSS and MC signals. DSSS signal is used for channel probing or to carry short messages. In this case, MS_j **1704** is transmitting both an MC signal and a DSSS signal to the base station BS_i **1702**. It is also under closed loop power control with the base station BS_i **1702**. In FIG. **17**, the mobile station MS_j **1704** is transmitting its DSSS signal simultaneously with its own MC signal. Other mobile stations (in this case, MS_l **1704** and MS_K **1704**) are transmitting either MC or DSSS signals to the base station BS_i **1702**.

FIG. **18** illustrates a typical channel response in the time domain **1802** and the frequency domain **1804**. By estimating the peaks of a channel response in the time domain **1802**, the channel profile in the frequency domain **1804** can be obtained. A typical channel response in the time domain and frequency domain for a broadband wireless system is shown in FIG. **18**. Using a matched filter in the DSSS receiver at the base station, the peaks of a channel response in time can be detected.

When closed loop power control is used, the initial power settings will be much more accurate than by using open loop power control alone. Thus, the margin reserved for power control inaccuracy can be reduced to a much smaller value. Furthermore, a bigger spreading factor can be used since no data information needs to be conveyed in the DSSS signal. This leaves a dynamic range large enough for detecting multi-path peaks from the output of the match filter or correlator, thereby generating a better channel profile. When and how often a mobile station should send the DSSS signal for channel probing is configurable by the network or the mobile station.

In one embodiment, the base station dictates the mobile station to transmit the channel probing DSSS when it needs an update of the mobile station's channel characteristics. In another embodiment, the base station polls the mobile station during its silent period and gets an update of the mobile station's information such as transmission timing and power from the probing DSSS signal. In yet another embodiment, the channel profile information is used by the base station to determine the proper modulation/coding and pilot pattern. In yet another embodiment, the channel profile information is used for advanced antenna techniques such as beamforming. In one embodiment, channel probing with the DSSS signaling is performed without close loop power control or time synchronization.

SHORT MESSAGE USING DSSS IN THE OVERLAY SYSTEM

In one embodiment of the invention, the DSSS signal is used to carry short messages. In this case, the mobile station is already synchronized in time and frequency with the base station, and its transmission of a MC signal is also under closed-loop power control with the base station. As shown in FIG. **17**, the mobile station MS_j is transmitting its DSSS signal carrying a short message simultaneously with its own MC signal. Other mobile stations (in this case, MS_l and MS_K) are transmitting either the MC signal or DSSS signal to the base station BS_i. In this case, the short message carried by the DSSS signal has a much lower data rate compared with that of the MC signal. In another embodiment, short messaging using the DSSS signaling is performed without close loop power control or time synchronization.

The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

Changes can be made to the invention in light of the above "Detailed Description." While the above description details certain embodiments of the invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Therefore, implementation details may vary considerably while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.

What is claimed is:

1. A mobile station comprising:

a transmitter configured to:

transmit, to a base station, a first uplink signal within a frequency band, wherein the first uplink signal is an orthogonal frequency division multiplexing (OFDM) signal and utilizes a frame format comprising a plurality of timeslots, each timeslot comprising a plurality of OFDM symbols;

transmit, to the base station, a random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station, wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and

a receiver configured to receive, from the base station, a response message.

2. The mobile station of claim **1**, wherein:

the receiver is configured to determine if the response message identifies the sequence associated with the base station in the random access signal; and

on a condition that the response message identifies the sequence associated with the base station in the random access signal, the transmitter is configured to transmit a second uplink signal.

3. The mobile station of claim **2**, wherein the response message includes power adjustment information and wherein the transmitter is configured to transmit the second uplink signal according to the power adjustment information.

4. The mobile station of claim **1**, wherein the portion of the frequency band used for transmission of the random access signal does not include control channels.

5. The mobile station of claim **1**, wherein the response message includes a mobile station identifier assigned to the mobile station.

6. The mobile station of claim **1**, wherein the time duration of the combination of the random access signal and the guard period is greater than a time duration of at least two of the plurality of OFDM symbols.

7. The mobile station of claim **1**, wherein the frequency band includes an outer portion and a center portion, wherein the portion of the frequency band for the random access signal is in the center portion and uplink control signals are sent in the outer portion.

8. The mobile station of claim **1**, wherein the random access signal is a spread spectrum signal.

9. The mobile station of claim **1**, wherein:

the receiver is further configured to receive broadcast information from the base station, the broadcast information indicating at least one sequence associated with the base station for use in producing the random access signal.

10. The mobile station of claim **1**, wherein the transmitter includes an OFDM transmitter signal processing circuit comprising: a serial to parallel converter, an inverse Fourier transform, and a cyclic prefix addition circuit; and

the OFDM transmitter signal processing circuit outputs the first uplink signal.

11. A method performed by a mobile station, the method comprising:

transmitting, to a base station, a first uplink signal within a frequency band, wherein the first uplink signal is an orthogonal frequency division multiplexing (OFDM) signal and utilizes a frame format comprising a plurality of timeslots, each timeslot comprising a plurality of OFDM symbols;

transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station, wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and

receiving, from the base station, a response message.

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

determining if the response message identifies the sequence associated with the base station in the random access signal; and

on a condition that the response message identifies the sequence associated with the base station in the random access signal, transmitting a second uplink signal.

13. The method of claim **12**, wherein the response message includes power adjustment information and wherein the second uplink signal is transmitted according to the power adjustment information.

14. The method of claim **11**, wherein the portion of the frequency band used for transmission of the random access signal does not include control channels.

15. The method of claim **11**, wherein the response message includes a mobile station identifier assigned to the mobile station.

16. The method of claim **11**, wherein the time duration of the combination of the random access signal and the guard period is greater than a time duration of at least two of the plurality of OFDM symbols.

17. The method of claim **11**, wherein the frequency band includes an outer portion and a center portion, wherein the portion of the frequency band for the random access signal is in the center portion and uplink control signals are sent in the outer portion.

18. The method of claim **11**, wherein the random access signal is a spread spectrum signal.

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

receiving broadcast information from the base station, the broadcast information indicating at least one sequence associated with the base station for use in producing the random access signal.

20. The method of claim **11**, wherein the first uplink signal is provided by an OFDM transmitter signal processing circuit comprising: a serial to parallel converter, an inverse Fourier transform, and a cyclic prefix addition circuit.

21. A mobile station comprising:

a first type of transmitter signal processing circuit configured to:

generate a first uplink signal, wherein the first uplink signal is an orthogonal frequency division multiplexing (OFDM) signal and utilizes a frame format comprising a plurality of timeslots, each timeslot comprising a plurality of OFDM symbols;

modulate the first uplink signal onto a first set of OFDM subcarriers;

a second type of transmitter signal processing circuit configured to generate an random access signal followed by a guard period, wherein the random access

signal includes a sequence associated with a base station, wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols;

a circuit configured to provide at least the first uplink signal or the random access signal to output a digital signal;

a digital-to-analog (D/A) conversion circuit configured to convert the digital signal to an analog signal;

wherein the mobile station is configured to transmit, to the base station, the analog signal in a frequency band, wherein the random access signal occupies in a frequency domain only a portion of the frequency band;

wherein the mobile station is further configured to receive, from the base station, a second analog signal; and

wherein the mobile station further comprises:

an analog-to-digital (A/D) conversion circuit configured to convert the second analog signal to a second digital signal; and

a receiver circuit configured to receive, based on the second digital signal, a response message.

22. The mobile station of claim **21**, wherein:

the receiver circuit is configured to determine if the response message identifies the sequence associated with the base station in the random access signal; and

on a condition that the response message identifies the sequence associated with the base station in the random access signal, the first type of transmitter signal processing circuit is configured to transmit a second uplink signal.

23. The mobile station of claim **22**, wherein the response message includes power adjustment information and wherein the first type of transmitter signal processing circuit is configured to transmit the second uplink signal according to the power adjustment information.

24. The mobile station of claim **21**, wherein the portion of the frequency band used for transmission of the random access signal does not include control channels.

25. The mobile station of claim **21**, wherein the response message includes a mobile station identifier assigned to the mobile station.

26. The mobile station of claim **21**, wherein the time duration of the combination of the random access signal and the guard period is greater than a time duration of at least two of the plurality of OFDM symbols.

27. The mobile station of claim **21**, wherein the frequency band includes an outer portion and a center portion, wherein the portion of the frequency band for the random access signal is in the center portion and uplink control signals are sent in the outer portion.

28. The mobile station of claim **21**, wherein the random access signal is a spread spectrum signal.

29. The mobile station of claim **21**, wherein:

the receiver circuit is further configured to receive broadcast information from the base station, the broadcast information indicating at least one sequence associated with the base station for use in producing the random access signal.

30. The mobile station of claim **21**, wherein:

the first type of transmitter signal processing circuit is an OFDM transmitter signal processing circuit comprising: a serial to parallel converter, an inverse Fourier transform, and a cyclic prefix addition circuit; and

the OFDM transmitter signal processing circuit outputs the first uplink signal.

* * * * *

Exhibit 3

US010075941B2

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

(10) **Patent No.: US 10,075,941 B2**
(45) **Date of Patent: Sep. 11, 2018**

(54) **METHODS AND APPARATUS FOR MULTI-CARRIER COMMUNICATION SYSTEMS WITH ADAPTIVE TRANSMISSION AND FEEDBACK**

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(*) 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.: **15/082,878**

(22) Filed: **Mar. 28, 2016**

(65) **Prior Publication Data**

US 2017/0055245 A1 Feb. 23, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/539,917, filed on Nov. 12, 2014, now Pat. No. 9,301,296, which is a continuation of application No. 13/246,677, filed on Sep. 27, 2011, now abandoned, which is a continuation of application No. 12/755,313, filed on Apr. 6, 2010, now Pat. No. 8,027,367, which is a continuation of application No. 10/583,529, filed as application No. PCT/US2005/004601 on Feb. 14, 2005, now Pat. No. 7,693,032.

(60) Provisional application No. 60/544,521, filed on Feb. 13, 2004.

(51) **Int. Cl.**

H04B 7/00	(2006.01)
H04W 72/04	(2009.01)
H04L 5/00	(2006.01)
H04L 27/26	(2006.01)
H04B 7/0413	(2017.01)
H04L 1/00	(2006.01)
H04W 52/26	(2009.01)

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

CPC ***H04W 72/0406*** (2013.01); ***H04B 7/0413*** (2013.01); ***H04L 1/0026*** (2013.01); ***H04L 1/0029*** (2013.01); ***H04L 1/0068*** (2013.01); ***H04L 1/0073*** (2013.01); ***H04L 5/006*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04L 5/0046*** (2013.01); ***H04L 5/0048*** (2013.01); ***H04L 27/2608*** (2013.01); ***H04W 72/044*** (2013.01); *H04L 1/0003* (2013.01); *H04L 1/0009* (2013.01); *H04L 5/0091* (2013.01); *H04W 52/26* (2013.01)

(58) **Field of Classification Search**

CPC .. H04W 72/044; H04B 7/0413; H04L 1/0026; H04L 1/0029; H04L 1/0068; H04L 5/006; H04L 5/0046

USPC 370/310, 328, 349, 350, 431, 436, 458

See application file for complete search history.

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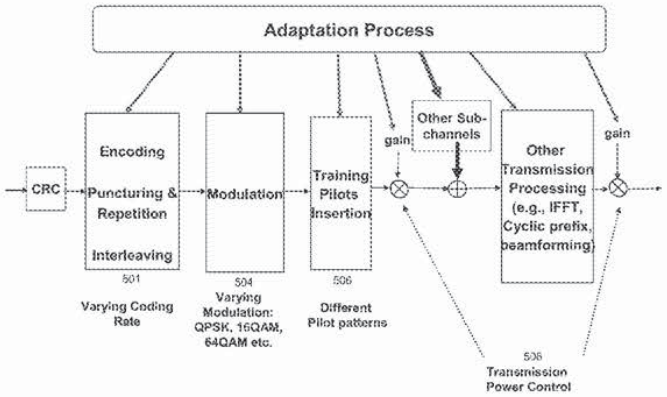
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(74) *Attorney, Agent, or Firm* — Perkins Coie LLP

(57) **ABSTRACT**

An arrangement is disclosed where in a multi-carrier communication system, the modulation scheme, coding attributes, training pilots, and signal power may be adjusted to adapt to channel conditions in order to maximize the overall system capacity and spectral efficiency without wasting radio resources or compromising error probability performance, etc.

14 Claims, 8 Drawing Sheets



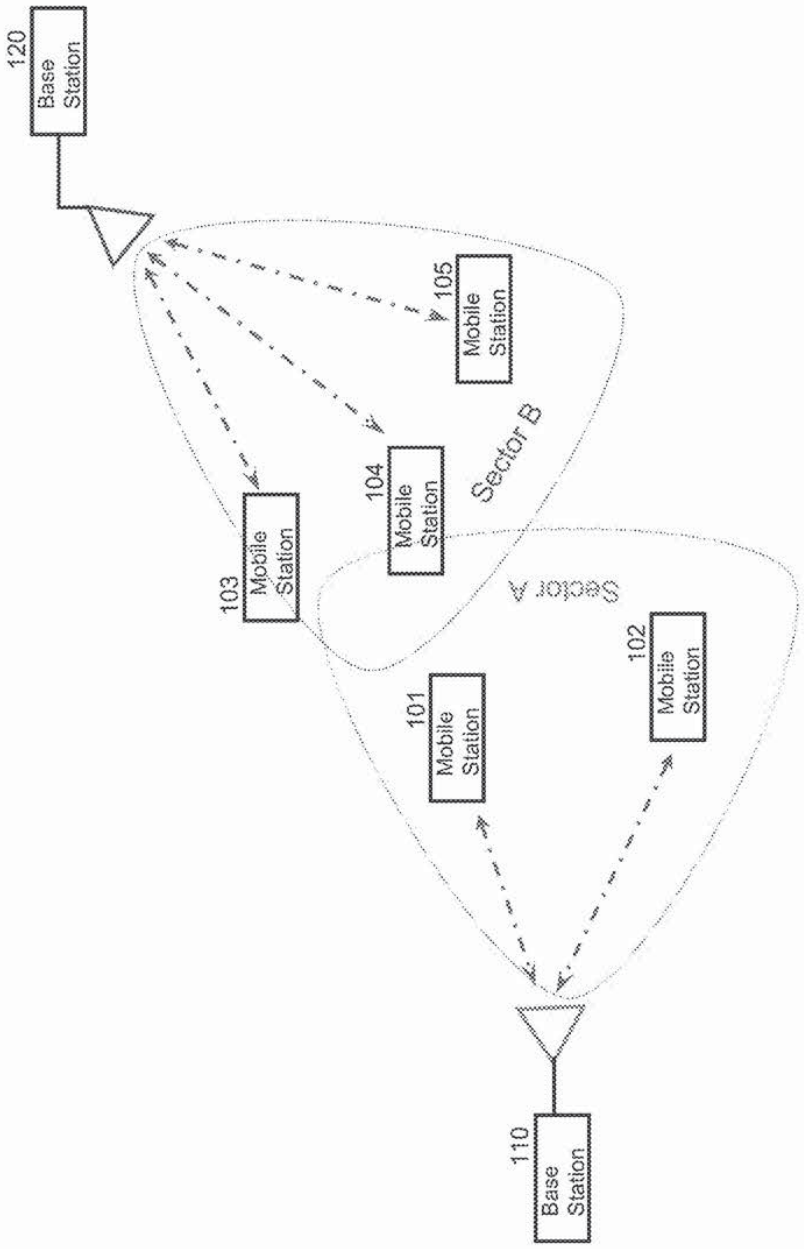

120
Base Station
105
Mobile Station
Sector B
104
Mobile Station
103
Mobile Station
Sector A
102
Mobile Station
101
Mobile Station
110
Base Station

FIG. 1

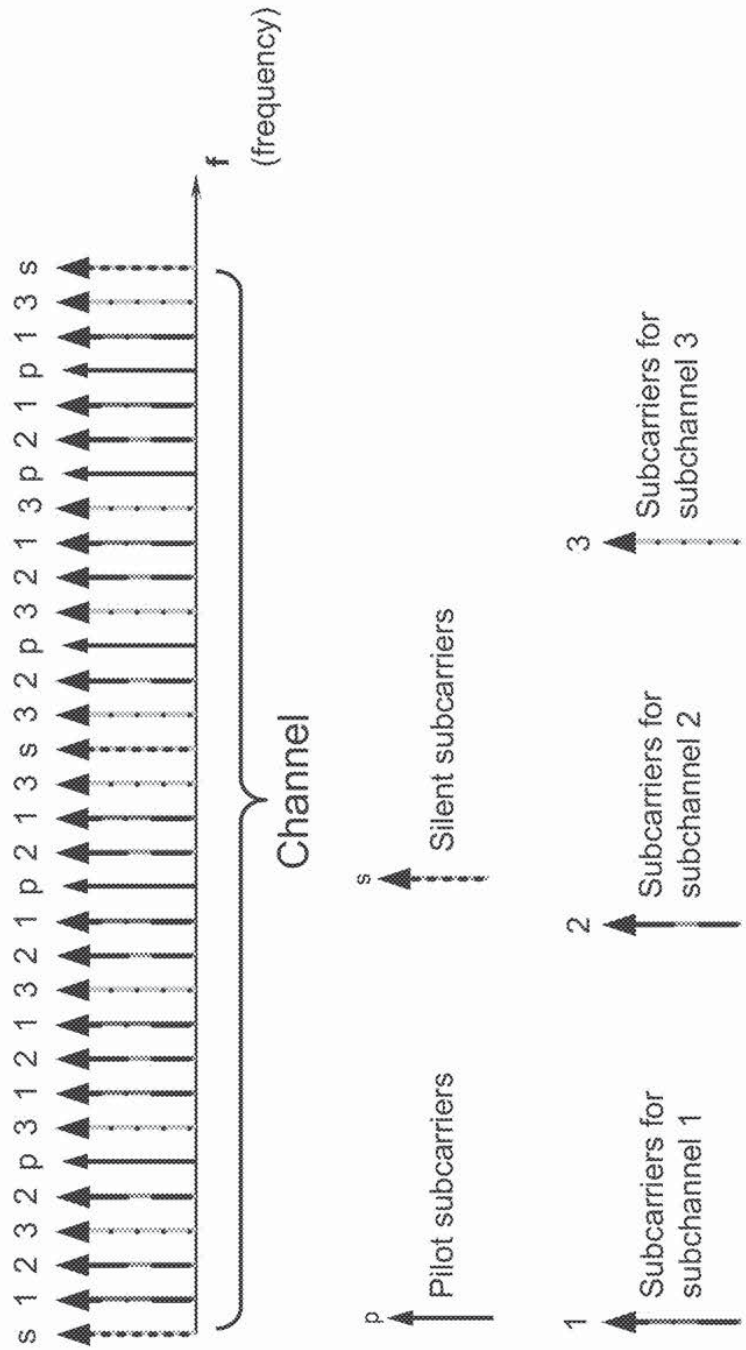

f
(frequency)
s 1 2 3 2 p 3 1 2 1 3 2 1 p 2 1 3 s 3 2 p 3 2 1 3 p 2 1 p 1 3 s
Channel
p
Pilot subcarriers
s
Silent subcarriers
1
Subcarriers for subchannel 1
2
Subcarriers for subchannel 2
3
Subcarriers for subchannel 3

FIG. 2

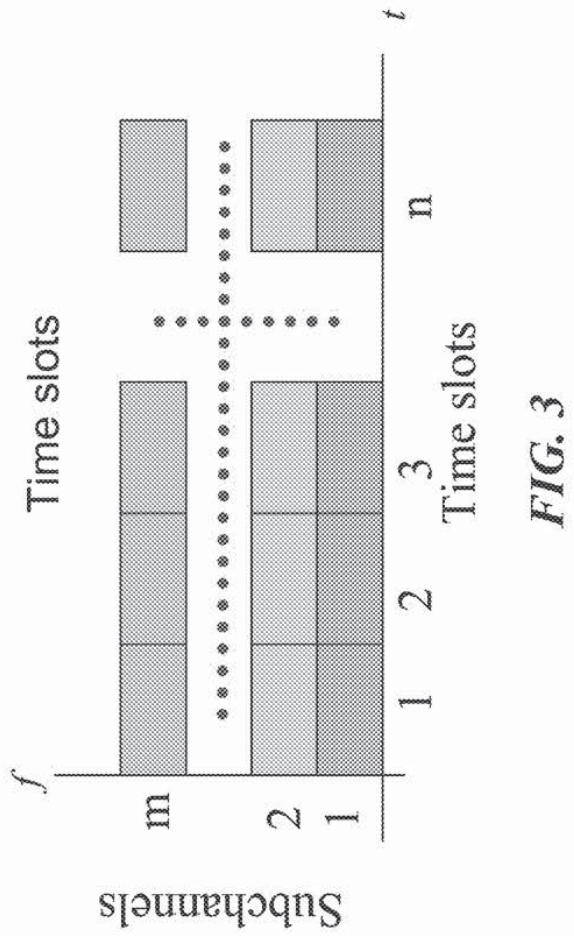


FIG. 3

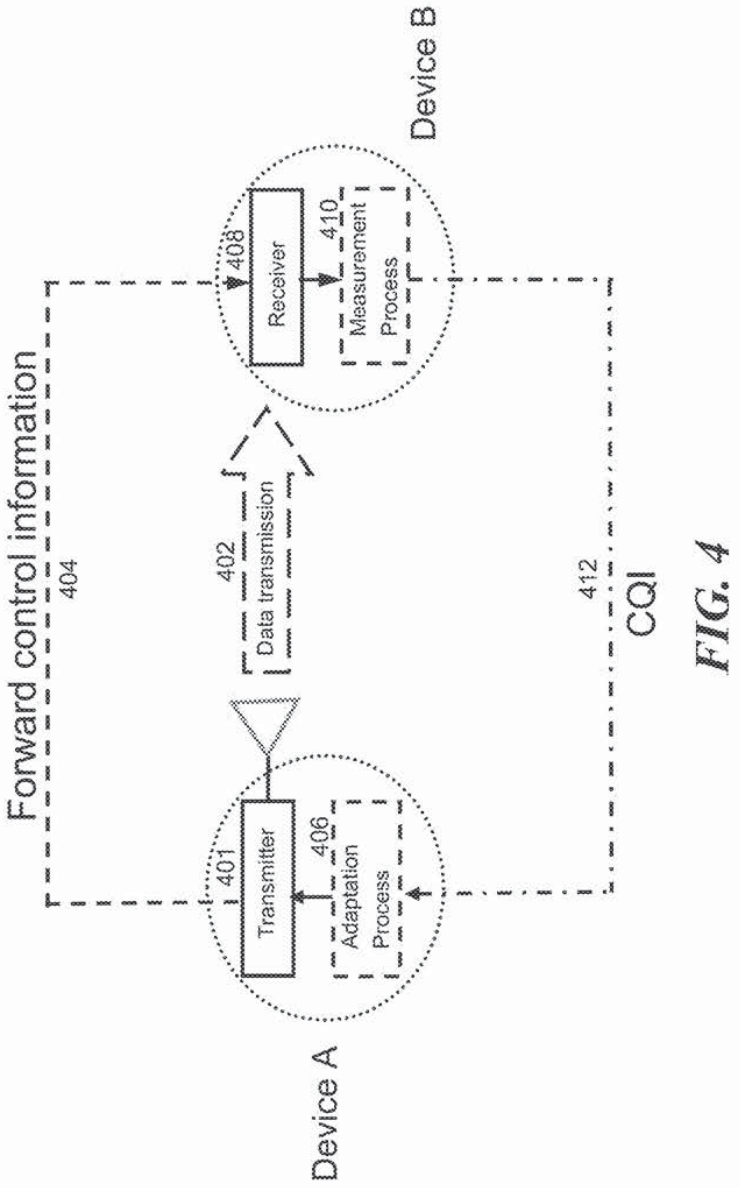

Device B
Receiver
408
Measurement
Process
410
Forward control information
404
402
Data transmission
412
CQI
Transmitter
401
Adaptation
Process
406
Device A

FIG. 4

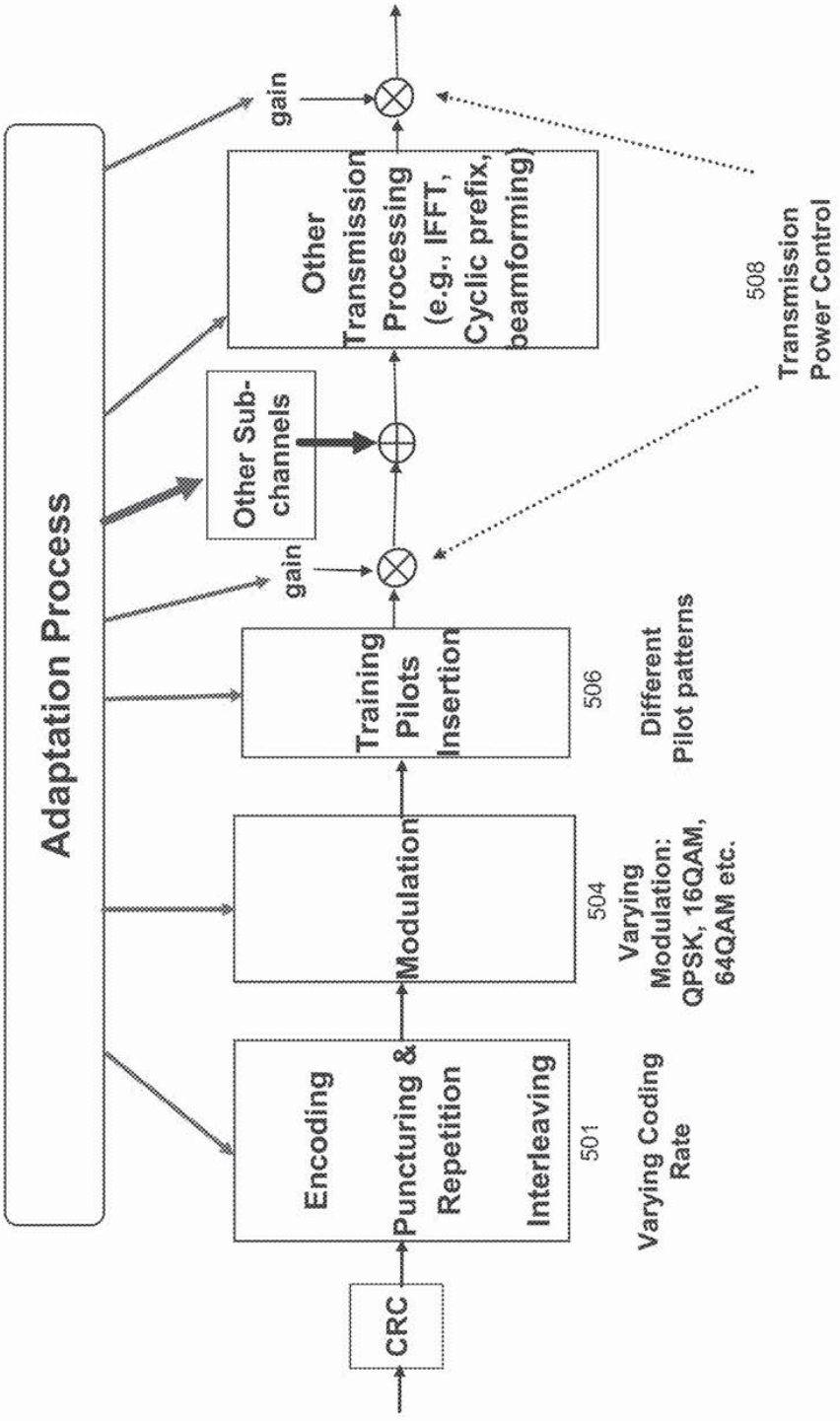

Adaptation Process
CRC
Encoding
Puncturing & Repetition
Interleaving
501
Varying Coding Rate
Modulation
504
Varying Modulation: QPSK, 16QAM, 64QAM etc.
Training Pilots Insertion
506
Different Pilot patterns
gain
Other Sub-channels
gain
Other Transmission Processing (e.g., IFFT, Cyclic prefix, beamforming)
508
Transmission Power Control

FIG. 5

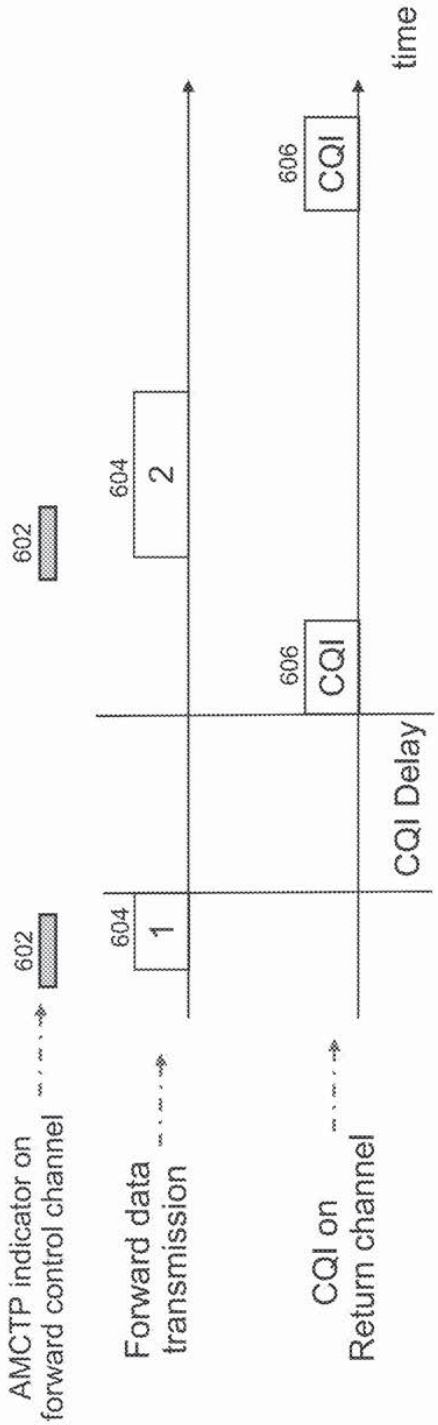

time
AMCTP indicator on forward control channel
602
Forward data transmission
604
1
602
604
2
CQI on Return channel
CQI Delay
606
CQI
606
CQI

FIG. 6

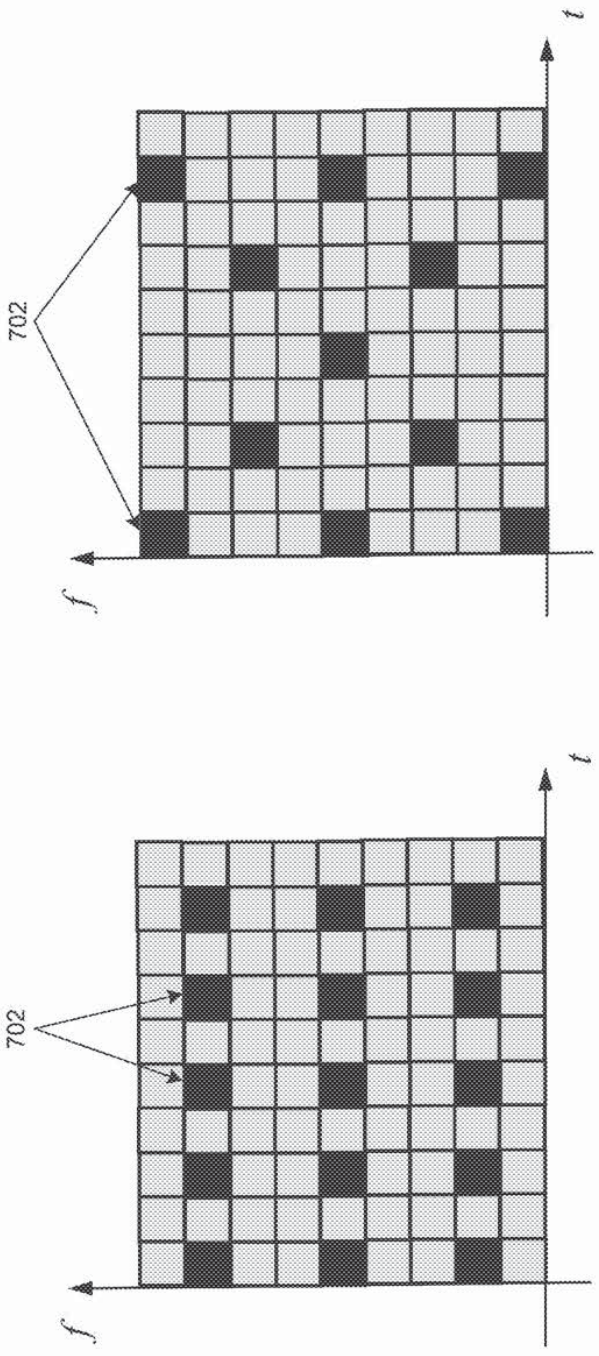


FIG. 7

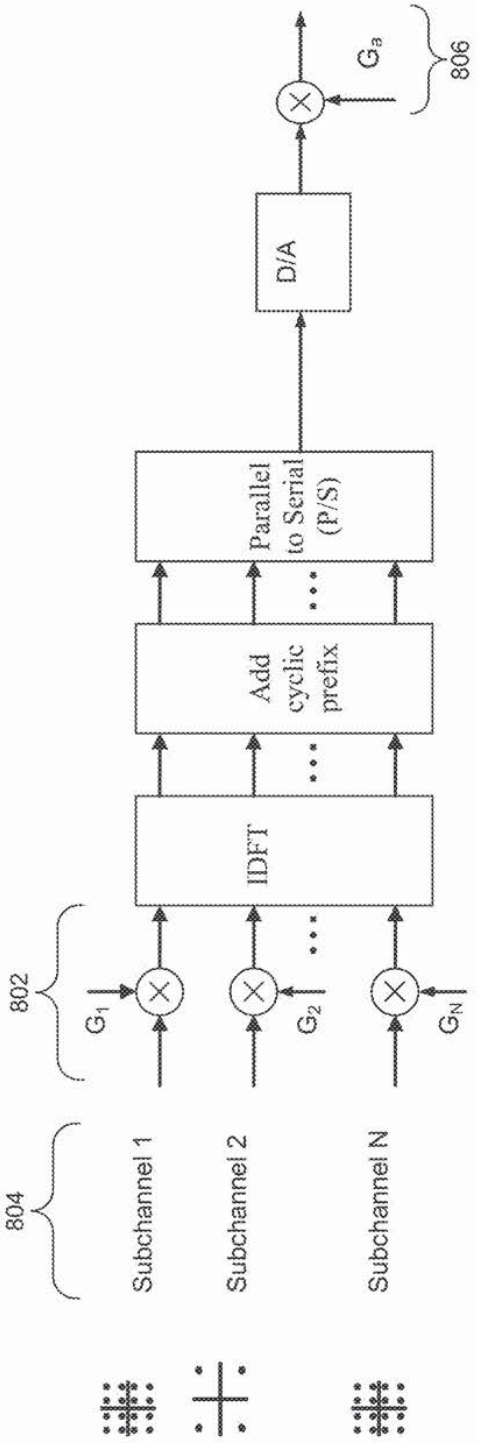

804
Subchannel 1
Subchannel 2
Subchannel N
802
G1
G2
GN
IDFT
Add cyclic prefix
Parallel to Serial (P/S)
D/A
Ga
806

FIG. 8

METHODS AND APPARATUS FOR MULTI-CARRIER COMMUNICATION SYSTEMS WITH ADAPTIVE TRANSMISSION AND FEEDBACK

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation application of, and incorporates by reference in its entirety, U.S. patent application Ser. No. 14/539,917, now granted U.S. Pat. No. 9,301,296, filed Nov. 12, 2014, which is a continuation application of U.S. patent application Ser. No. 13/246,677, filed Sep. 27, 2011, which is a continuation application of U.S. patent application Ser. No. 12/755,313, now granted U.S. Pat. No. 8,027,367, filed Apr. 6, 2010, which is a continuation application of U.S. patent application Ser. No. 10/583,529, now granted U.S. Pat. No. 7,693,032, having a 371 date of May 10, 2007, which is a national stage application of International Application No. PCT/US2005/004601, filed Feb. 14, 2005, which claims the benefit of U.S. Provisional Patent Application No. 60/544,521, filed Feb. 13, 2004. This application also relates to PCT Application No. PCT/US05/03518 titled "Methods and Apparatus for Overlaying Multi-Carrier and Direct Sequence Spread Spectrum Signals in a Broadband Wireless Communication System," filed Jan. 27, 2005, which claims the benefit of U.S. Provisional Application No. 60/540,032 filed Jan. 29, 2004 and U.S. Provisional Application No. 60/540,586 filed Jan. 30, 2004.

BACKGROUND

Adaptive modulation and coding (AMC) has been used in wireless systems to improve spectral efficiency in a fading environment where signal quality varies significantly. By adjusting the modulation and coding scheme (MCS) in accordance with the varying signal-to-interference-plus-noise ratio (SINR), reliable communication link can be maintained between communicating devices. For example, in CDMA2000 1×EV-DO system, twelve different modulation/coding schemes are provided. AMC is also used in CDMA2000 1×EV-DV and 3GPP HSDPA systems.

To improve performance, in addition to the MCS, other system functions such as channel estimation, transmission power control (TPC), and subchannel configuration can be adjusted in accordance with the state of the communication channel. For example, channel estimation typically utilizes training symbols or pilot data, which are known to both the transmitter and the receiver. For coherent modulation, the channel information can be extracted at the receiver by comparing the pilots and their corresponding received versions. For non-coherent modulation, the received samples of the pilots are used as reference for the detection of the transmitted data.

Channel estimation is an important part of multi-carrier (MC) communication systems such as Orthogonal Frequency Division Multiplexing (OFDM) systems. In conventional OFDM systems, such as IEEE802.11a, 802.11g, 802.16, or DVB-T system, pilots are transmitted for channel estimation. The pilots are fixed and form part of other functions such as MCS, TPC, and subchannel configuration in some wireless systems.

Fast TPC can compensate for fast fading. In a multi-cell multiple-access system, TPC is also used to reduce intra-cell and inter-cell interference and to conserve battery life for the mobile station by transmitting with only necessary power.

TPC is one of many functions in some wireless systems, along with MCS, pilot attributes, subchannel configuration, etc.

The subchannel configuration is normally defined and fixed in an operation, and it is usually not considered an adjustable function of the system to be adapted to the user profile and/or operational environment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a representative cellular communication system.

FIG. **2** is a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers.

FIG. **3** depicts a radio resource divided into small units in both frequency and time domains: subchannels and time slots.

FIG. **4** is an illustration of a control process between Device A and Device B, each of which can be a part of a base station and a mobile station depicted in FIG. **1**.

FIG. **5** illustrates a joint adaptation process at a transmitter of an OFDM system which controls coding, modulation, training pilot pattern, and transmission power for a subchannel.

FIG. **6** is an illustration of a control messaging associated with data transmission between communication devices.

FIG. **7** illustrates two different training pilot patterns plotted for a multi-carrier system.

FIG. **8** illustrates a power control in AMCTP scheme for an OFDM system.

DETAILED DESCRIPTION

Methods and apparatus for adaptive transmission of wireless communication signals are described, where MCS (modulation and coding scheme), coding rates, training pilot patterns, TPC (transmission power control) levels, and subchannel configurations are jointly adjusted to adapt to the channel conditions. This adaptation maximizes the overall system capacity and spectral efficiency without wasting radio resources or compromising error probability performance.

Furthermore, the subchannel composition is designed to be configurable so that it can be adjusted statically or dynamically according to the user profiles or environmental conditions. The methods for obtaining the channel information and for transmitting the control information in the joint adaptation scheme are also described below, such as feedback of channel condition and indexing of the joint scheme, along with methods for reducing the overhead of messaging.

The mentioned multi-carrier system can be of any special format such as OFDM, or Multi-Carrier Code Division Multiple Access (MC-CDMA) and can be applied to downlink, uplink, or both, where the duplexing technique is either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

The apparatus and methods are described with respect to various embodiments and provide specific details for a thorough understanding and enablement. One skilled in the art will understand that the invention may be practiced without such details. In some instances well-known structures and functions are not shown or described in detail to avoid unnecessarily obscuring the description of the embodiments.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is

to say, in the sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

The content of this description is applicable to a communication system with multiple transmitters and multiple receivers. For example, in a wireless network, there are a number of base stations, each of which provides coverage to its designated area, typically called a cell. Within each cell, there are mobile stations. FIG. **1** illustrates a communication system that is representative of such a system, where Base Station **110** is communicating with Mobile Stations **101** and **102** in Sector A of its cell site while Base Station **120** is communicating with Mobile Stations **103**, **104**, and **105** in Sector B of its cell site.

A multi-carrier multiple-access system is a special case of general communication systems and hereinafter is employed as a representative communication system to describe the embodiments of the invention.

Multi-Carrier Communication System

The physical media resource (e.g., radio or cable) in a multi-carrier communication system can be divided in both the frequency and the time domains. This canonical division provides a high flexibility and fine granularity for resource sharing.

The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. Within a particular spectral band or channel, there are a fixed number of subcarriers, and there are three types of subcarriers:

1. Data subcarriers, which carry information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are used for assisting system functions such as estimation of system parameters; and
3. Silent subcarriers, which have no energy and are used for guard bands and DC carrier.

The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The carriers forming one subchannel are not necessarily adjacent to each other. Each user may use part or all of the subchannels. The concept is illustrated in FIG. **2**, which is the basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers. Data subcarriers can be grouped into subchannels in a specified manner. The pilot subcarriers are also distributed over the entire channel in a specified manner.

The basic structure of a multi-carrier signal in the time domain is made up of time slots to support multiple-access. The resource division in both the frequency and time domains is depicted in FIG. **3**, which is the radio resource divided into small units in both the frequency and time domains (subchannels and time slots). The basic structure of a multi-carrier signal in the time domain is made up of time slots.

Adaptive Transmission and Feedback

The underlying principles of adaptive transmission and feedback are both to increase the degree of freedom of a transmission process and to supply information for the adaptation process of a communication system. The adaptation process adjusts the allocated modulation schemes, coding rates, pilot patterns, power levels, spatial processing schemes, subchannel configurations, etc. in accordance with the transmission channel state and condition, for improving system performance and/or capacity.

Below, AMCTP (adaptive modulation, coding, training and power control) is used as a general term, where its variations can be applied to appropriate applications. There are different adaptive transmission schemes that are subsets of the AMCTP scheme, such as AMCT (adaptive modulation, coding and training), AMTP (adaptive modulation, training, and power control), AMT (adaptive modulation and training), and so forth.

FIG. **4** is an illustration of the control process between Device A and Device B, each of which can be a part of a base station and a mobile station depicted in FIG. **1**, during adaptive transmission. The transmitter **401** of Device A transmits data **402** and associated control information **404** to Device B, based on an output of the adaptation process **406**. After a receiver **408** of Device B receives the transmitted data **402** and control information **404**, a measurement process **410** of Device B measures a channel conditions and feeds a channel quality information (CQI) **412** back to Device A.

The granularity of AMCTP schemes in a multi-carrier system can be user-based, where one or multiple subchannels may be used, or the granularity can be subchannel-based, where a subchannel may contain one or more subcarriers. Likewise, the granularity of CQI can be user- or subchannel-based. Both AMCTP and CQI may change over time and may differ from one time slot to another.

FIG. **5** illustrates a joint adaptation process at a transmitter of an OFDM system which employs separate processing block to control the coding **502**, modulation **504**, training pilot pattern **506**, and transmission power for a subchannel **508**. Each block may be implemented combined or separately in circuitry, in dedicated processors, in a digital signal processor, as a microprocessor implemented subroutine, etc.

FIG. **6** is an illustration of control messaging associated with the data transmission between communication devices, such as Device A and B in FIG. **4**. In FIG. **6** the AMCTP indicator **602** is associated with data transmission **604** on a forward link from the transmitter to the receiver, and CQI **606** is associated with the information feedback from the receiver to the transmitter on a return channel.

In a system where AMCTP is used, the transmitter relies on the CQI to select an appropriate AMCTP scheme for transmitting the next packet, or retransmitting a previously failed packet, required in an automatic repeat request (ARQ) process. The CQI is a function of one or more of the following: received signal strength; average SINR; variance in time; frequency or space; measured bit error rate (BER); frame error rate (FER); or mean square error (MSE). Channel conditions hereinafter are referred to as one or more of the following, for a user or a subchannel: signal level, noise level, interference level, SINR, fading channel characteristics (Doppler frequency, delay spread, etc.), or channel profile in time or frequency domain. The detection of the channel condition can be at the transmitter, the receiver, or both.

An MCS in AMCTP is referred to as a modulation and error correction coding scheme used in the system. By matching an MCS to a specific channel condition (e.g., SINR level), a better throughput is achieved. Varying only the MCS is a sub-optimal approach since other factors such as training pilot patterns or subchannel compositions also impact system performance.

A pilot pattern includes the number of (training) pilot symbols, the location of the symbols in time/frequency/space, the amplitude and phase, and other attributes of these symbols. The system may use distinctive pilot patterns to suit different MCS and channel conditions. The pilot pattern requirements for a robust channel estimation vary with the SINR of the channel and the channel profile.

In a multi-carrier system, pilots are transmitted on certain positions in the time-frequency grid. FIG. **7** illustrates two of many different training pilot patterns that may be used, each plotted for a multi-carrier system, where the dark shaded time-frequency grids **702** are allocated as training pilot symbols. One criterion for choosing a pilot pattern is that the pilot assisted channel estimation should not be a bottleneck for the link performance, and that the pilot overhead should be kept to a minimum. The joined adaptation of training pilot pattern together with MCS is a more effective way of matching the channel conditions, and results in a better performance compared with a mere adaptation of MCS.

The power control information may include an absolute power level and/or a relative amount to increase or decrease the current power setting. In a multi-carrier system, the power levels of different subchannels are set differently such that minimum power is allocated to a subchannel to satisfy its performance requirements while minimizing interference to other users.

The power control can be user- or subchannel-based. FIG. **8** is an illustration of a power control in an OFDM system where digital variable gains **802** G**1**, G**2** . . . GN are applied to subchannels **804** that may have different MCSs with different transmission power levels. Analog domain gain 806 Ga is used to control the total transmission power signal processes to meet the requirements of the transmission power of the device. In FIG. **8**, after variable gains are applied to subchannels **804**, they are inputted to the inverse discrete Fourier transform (IDFT) module. The outputs from the IDFT are the time domain signals, which are converted from parallel to sequential signals after a cyclic prefix is added to them.

Table 1 is an example of a general AMCTP table (or CQI table). It should be noted that some pilot patterns in the table can be the same. The total number of indexes used to represent different combinations of the joint adaptation process can be different for AMCTP index and CQI index. For instance, it is not necessary to send absolute transmission power information to the receiver(s). Some AMCTP information, such as relative power control or code rate, can be embedded in the data transmission instead of being conveyed in the AMCTP index.

TABLE 1

An example of general AMCTP.

Index	Modulation	Code Rate	Training Pilot	Transmit Power
1	QPSK	1/16	Pattern 1	+
2	QPSK	1/8	Pattern 2	+
3	QPSK	1/4	Pattern 3	+
4	QPSK	1/2	Pattern 4	+
5	QPSK	1/2	Pattern 5	+
6	16QAM	1/2	Pattern 6	+
7	16QAM	1/2	Pattern 7	+
8	16QAM	3/4	Pattern 8	+
9	16QAM	3/4	Pattern 9	+
10	64QAM	2/3	Pattern 10	+
11	64QAM	5/6	Pattern 11	+
12	64QAM	5/6	Pattern 12	Max-1x
13	64QAM	5/6	Pattern 13	Max-2x
14	64QAM	5/6	Pattern 14	Max-3x

In a general AMCTP or CQI table, different training pilot patterns may be used for different modulations and code rates. However, even for the same modulation and coding, different patterns can be used to match different channel conditions. In order to make the table more efficient, more indexes can be allocated to the more frequently used scenarios. For example, several training pilot patterns can be allocated to the same MCS that is used more frequently, to achieve finer granularity and thus have a better match with different channel conditions.

Table 2 is a simple realization of the AMCTP index or the CQI index. In one embodiment, as shown in Table 2, the AMCTP and CQI index is Gray coded so that one bit error in the index makes the index shift to the adjacent index.

In some cases, a different number of pilot symbols is used for the same MCS. In one embodiment, to keep the packet size the same when the same MCS is used with a different number of pilot symbols, rate matching schemes such as repetition or puncturing is employed. For instance in Table 2, for Index 010 and Index 011, Pattern 3 has more pilot symbols compared to Pattern 2. The code rate of Index 010 is ½, which is punctured to 7/16 for Index 011 to accommodate the extra pilot symbols. In one embodiment, more significant bits in the CQI index are protected with stronger error protection code on the return channel.

TABLE 2

Another example of AMCTP or CQI table.

Index (Gray coded)	Modulation	Code Rate	Training Pilot	Transmit Power
000	QPSK	1/4	Pattern 1	Max
010	QPSK	1/2	Pattern 2	Max
011	QPSK	7/16	Pattern 3	Max
001	16QAM	1/2	Pattern 2	Max
101	16QAM	7/16	Pattern 3	Max
111	64QAM	2/3	Pattern 2	Max
110	64QAM	5/8	Pattern 3	Max
100	64QAM	5/6	Pattern 3	Max-X

Other factors that can be used in the adaptation process include modulation constellation arrangements, transmitter antenna techniques, and subchannel configuration in a multi-carrier system.

For some modulation schemes such as 16QAM and 64QAM, how information bits are mapped to a symbol determines the modulation schemes' reliability. In one embodiment, constellation arrangement is adjusted in the adaptation process to achieve a better system performance, especially during retransmission in a hybrid ARQ process.

Some multiple antenna techniques, such as transmission diversity, are used to improve the transmission robustness against fading channel effects, whereas other multiple antenna techniques such as multiple-input multiple-output (MIMO) schemes are used to improve transmission throughput in favorable channel conditions. In one embodiment of the adaptive transmissions the antenna technique used for a transmission is determined by the adaptation process.

In a multi-carrier multi-cell communication system, when all subcarriers in one subchannel are adjacent or close to each other, they are more likely to fall in the coherent bandwidth of a fading channel; thus they can be allocated to users that are either fixed in location or are move slowly. On the other hand, when subcarriers and/or subchannels that belong to one user are scattered in the frequency domain, it results in higher diversity gains for the fast moving users, and a better interference averaging effect.

Given the fact that different configurations of subchannel compositions are suitable for different scenarios or user profiles, subchannel configuration is included in the transmission adaptation process. In one embodiment, the subchannel configuration information is broadcast on the common forward control channel to all users such that each user is informed of its subchannel configuration.

In another embodiment, the subchannel configuration is adjusted according to deployment scenarios. For instance, when a base station is newly deployed with less interference, one form of subchannel configuration is used, and when more users join the network or more adjacent base stations are deployed, which results in stronger interference to the users in the system, a different subchannel configuration with better interference averaging effect is used.

The following paragraphs describe a method of transmitting the control message between the transmitter and receiver, when the AMCTP scheme is implemented. A forward control link is defined here as the transmission of the AMCTP indicator from the transmitter to the receiver, and a return control channel is defined as the transmission of CQI, as the feedback information, from the receiver to the transmitter, as shown in FIG. **4**.

The AMCTP indicator on the forward link can be sent either separately or jointly. For instance, the power control information, training pilot pattern indicator, or antenna diversity scheme can be embedded in the data transmission. In another embodiment, AMCTP is transmitted on a separate control channel with stronger error protection.

One way for the transmitter to obtain CQI is to have it explicitly sent from the receiver to the transmitter based on channel condition measurements at the receiver during previous transmission(s). The CQI is then used by the transmitter to determine what AMCTP scheme to use for the next transmission. In one embodiment, CQI for one user is periodically updated on the return channel, even when there is no forward transmission targeted for that user. In this case the receiver measures the channel conditions from the common broadcast transmission or the data transmission targeted to other users.

In one embodiment, the transmitter or the receiver uses any of several known predictive algorithms to predict current or future channel conditions based on previous channel measurements. This is more effective for a fast fading environment where the past measurements may not match the current transmission closely, due to the fast channel variations. The output of the predictive algorithm is then used by the adaptation process to select the best possible scheme for the current transmission.

Another method to obtain CQI is through the transmission of a probing sequence from the receiver to the transmitter on the return channel. In one embodiment, in a multi-carrier communication system, a probing sequence is transmitted from the receiver to the transmitter using an overlay scheme where the probing sequence is overlaid to the data traffic without having negative impact on the data transmission performance. In this case the transmitter estimates the channel profile in the time and/or frequency domains based on the received probing sequence. This is especially effective for TDD systems due to the reciprocity of the channel conditions on forward and reverse channels.

The AMCTP indicator or CQI can be sent per user or per subchannel. In one embodiment if per subchannel feedback is employed, since the AMCTP and CQI information for the same users are highly correlated, first the source coding is employed to compress the CQI, and then the error correction coding is applied to the compressed CQI to provide sufficient error protection.

In another embodiment, in hybrid ARQ retransmission, the transmitter may not use the requested CQI for the retransmission, while it may use the requested CQI for a new packet transmission. Instead, in this embodiment, it selects an AMCTP scheme that is appropriate for the retransmission at the same power level as in the previous transmission(s), in order to reduce interference with other users.

It should be pointed out that the AMCTP index used for the transmission from the transmitter to the receiver may be different from the CQI that the receiver requested, because the transmitter may have other considerations such as quality of service (QoS) for different users, network traffic load, and power allocation limit.

The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

Changes can be made to the invention in light of the above "Detailed Description." While the above description details certain embodiments of the invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Therefore, implementation details may vary considerably while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional

claims after filing the application to pursue such additional claim forms for other aspects of the invention.

We claim:

1. A link adaptation method by a base station serving a plurality of mobile stations in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the method comprising:

transmitting a control message to a mobile station over a control channel,

wherein:

the control message contains transmission parameters allocated to the mobile station for a subsequent transmission of data by the base station over a frequency subchannel to the mobile station in a time slot; and

the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and

transmitting a data packet to the mobile station over the frequency subchannel in accordance with the mobile station-specific transmission parameters.

2. The method in claim 1, wherein the mobile station-specific transmission parameters further indicate a training pilot pattern.

3. The method in claim 1, wherein the mobile station-specific transmission parameters further indicate power control information.

4. The method in claim 1, wherein the antenna transmission scheme is based on a channel condition.

5. The method in claim 1, wherein the corresponding subchannel configuration is selected based on a channel condition.

6. A base station serving a plurality of mobile stations in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the base station comprising a transmitter configured to:

transmit a control message to a mobile station over a control channel, wherein:

the control message contains transmission parameters allocated to the mobile station for a subsequent transmission of data by the base station over a frequency subchannel to the mobile station in a time slot; and

the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and

transmitting a data packet to the mobile station over the frequency subchannel in accordance with the mobile station-specific transmission parameters.

7. The base station in claim 6, further comprising a receiver configured to receive channel state information from the mobile station.

8. A link adaptation method by a mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the method comprising:

receiving a control message from the serving base station over a control channel,

wherein:

the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and

the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and

receiving a data packet transmitted by the serving base station using the mobile station-specific transmission parameters over the frequency subchannel.

9. The method in claim 8, wherein the mobile station-specific transmission parameters further indicate a training pilot pattern.

10. The method in claim 8, wherein the mobile station-specific transmission parameters further indicate power control information.

11. The method in claim 8, wherein the MIMO scheme is for improving transmission throughput based on a channel condition.

12. The method in claim 8, wherein the corresponding subchannel configuration is selected based on a channel condition.

13. A mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the mobile station comprising a receiver configured to:

receive a control message from the serving base station over a control channel,

wherein:

the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and

the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and

receive a data packet transmitted by the serving base station using the mobile station-specific transmission parameters over the frequency subchannel.

14. The mobile station in claim 13, further comprising a transmitter configured to transmit channel state information to the serving base station.

* * * * *

Exhibit 4

US010447450B2

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

(10) **Patent No.: US 10,447,450 B2**
(45) **Date of Patent: *Oct. 15, 2019**

(54) **METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD**

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(73) Assignee: **Neocific, Inc.**, Bellevue, WA (US)

(*) 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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(21) Appl. No.: **15/676,421**

(22) Filed: **Aug. 14, 2017**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(Continued)

(51) **Int. Cl.**

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H04L 27/26	(2006.01)
H04L 1/00	(2006.01)
H04W 72/04	(2009.01)
H04J 11/00	(2006.01)
H04W 52/14	(2009.01)

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

CPC ***H04L 5/0053*** (2013.01); ***H04J 11/005*** (2013.01); ***H04L 1/0003*** (2013.01); ***H04L 1/0009*** (2013.01); ***H04L 1/0029*** (2013.01); ***H04L 5/006*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04L 5/0044*** (2013.01); ***H04L 27/2601*** (2013.01); ***H04W 52/146*** (2013.01); ***H04W 72/04*** (2013.01); ***H04W 72/048*** (2013.01); *H04L 5/0094* (2013.01)

(58) **Field of Classification Search**

CPC H04L 5/0053; H04L 1/0003; H04J 11/005

See application file for complete search history.

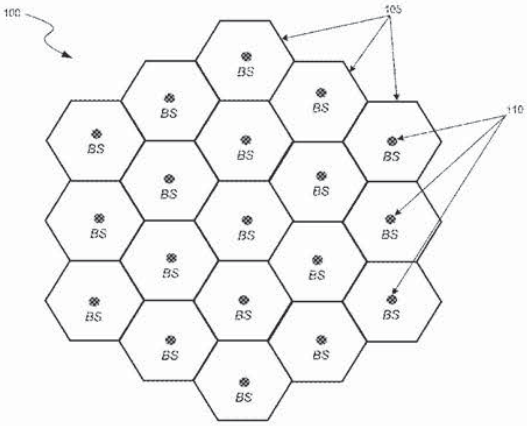
Primary Examiner — Chandrahas B Patel

(74) *Attorney, Agent, or Firm* — Perkins Coie LLP

(57) **ABSTRACT**

A method and system for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information. In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead.

18 Claims, 12 Drawing Sheets



Related U.S. Application Data

application No. PCT/US2006/038149 on Sep. 28, 2006, now Pat. No. 7,948,944.

(60) Provisional application No. 60/721,451, filed on Sep. 28, 2005.

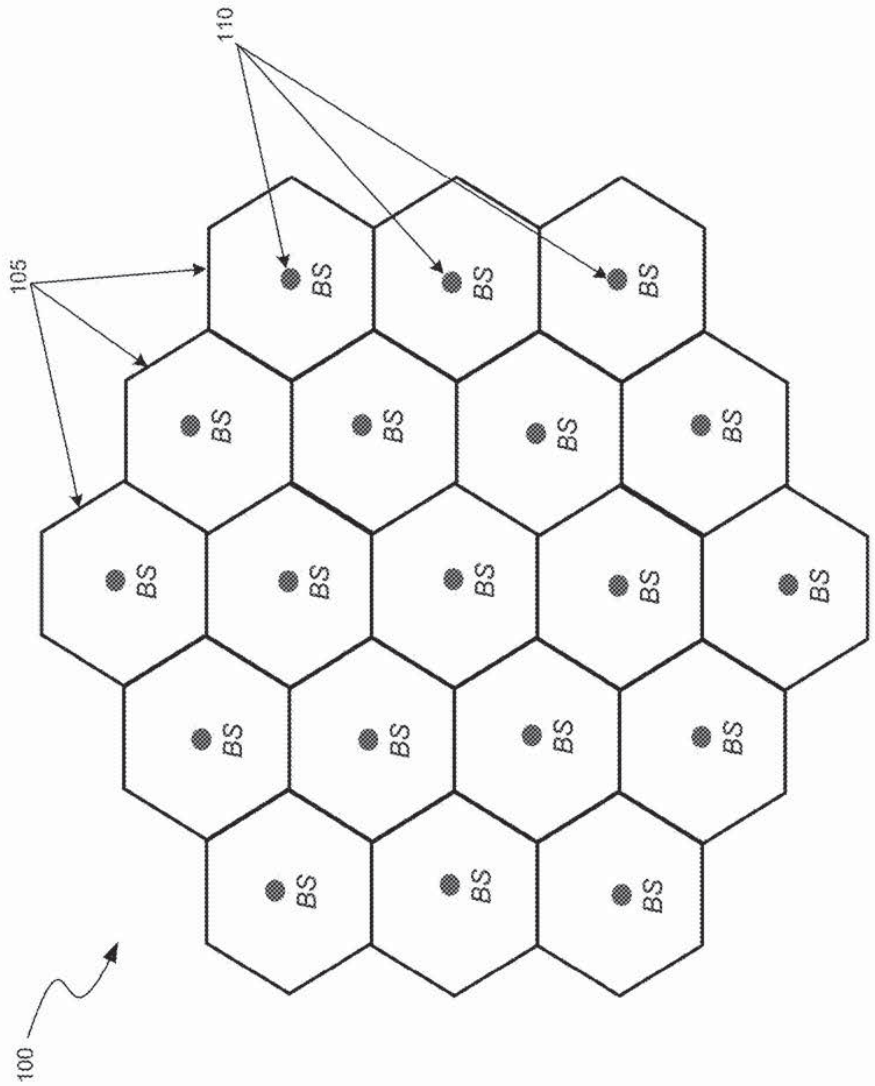


FIG. 1

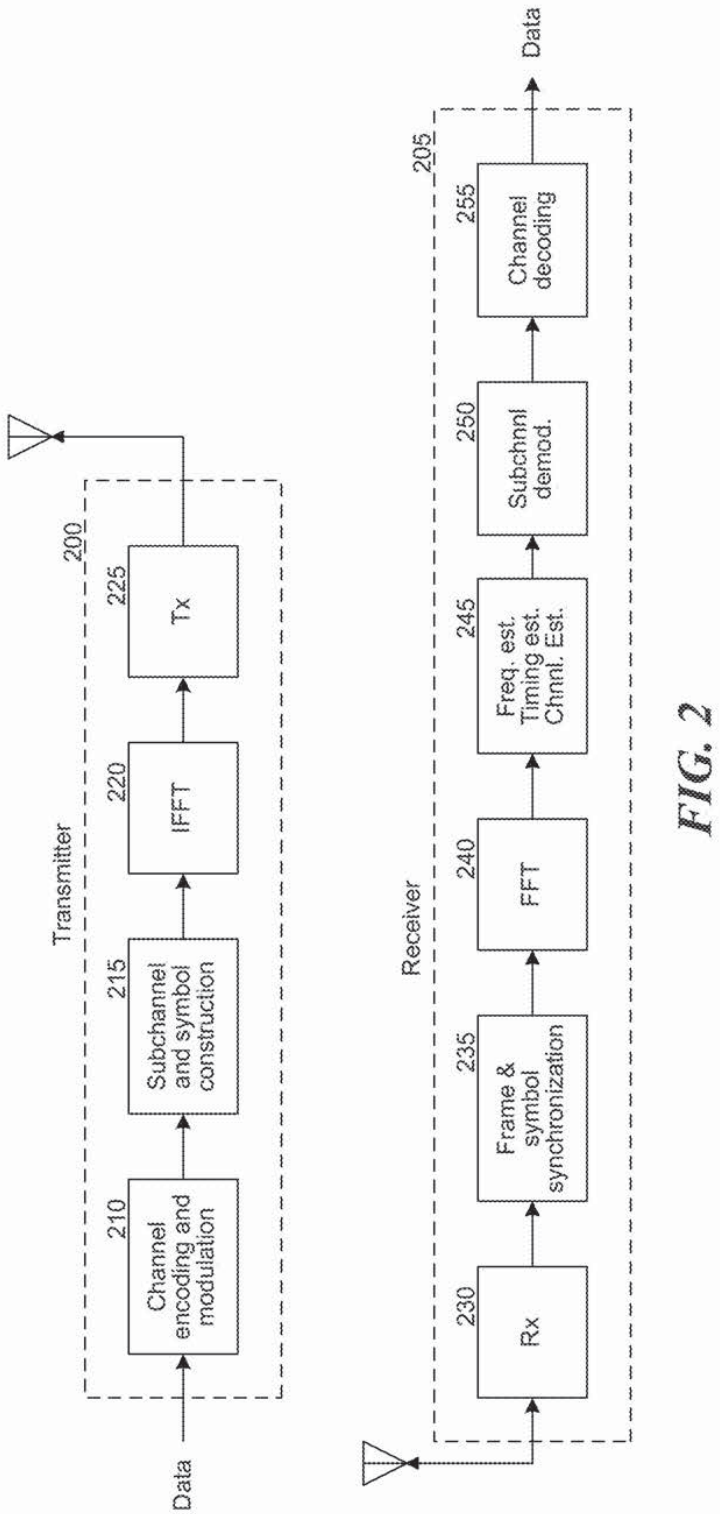

Transmitter
200
Data
210
Channel encoding and modulation
215
Subchannel and symbol construction
220
IFFT
225
Tx
Receiver
205
Rx
230
Frame & symbol synchronization
235
FFT
240
Freq. est. Timing est. Chnnl. Est.
245
Subchnnl demod.
250
Channel decoding
255
Data

FIG. 2

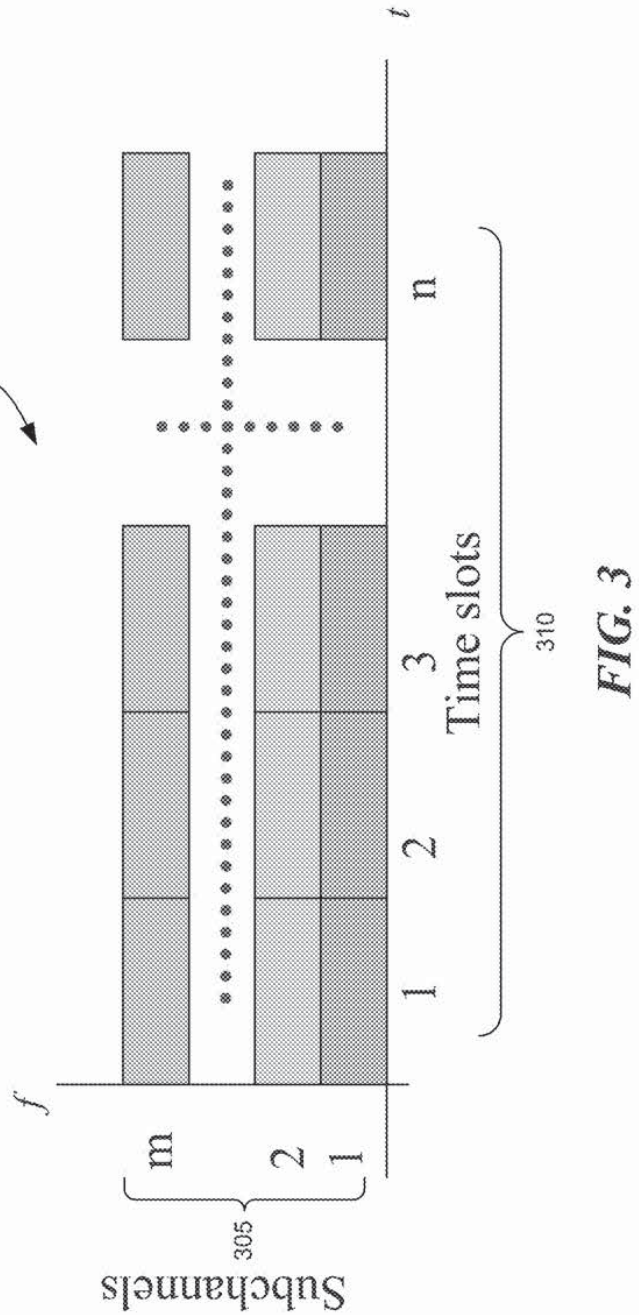


FIG. 3

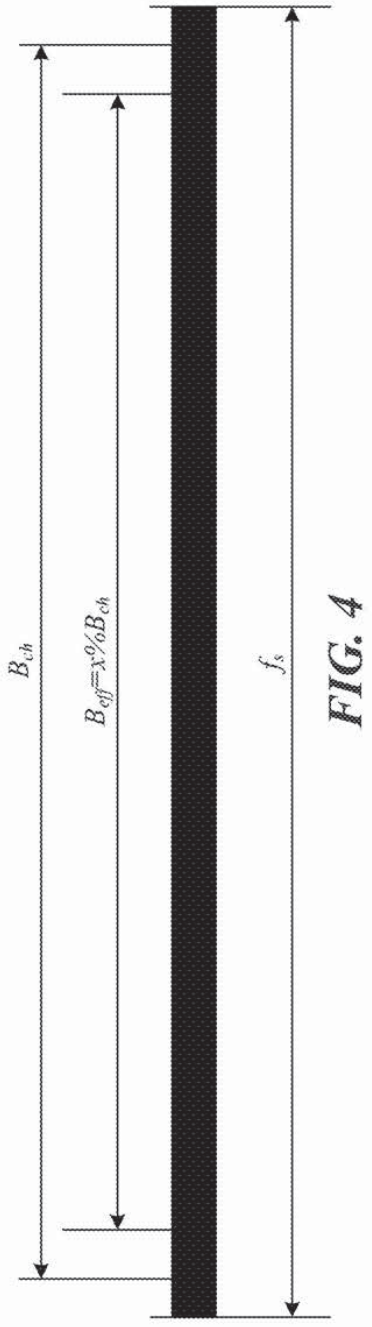


FIG. 4

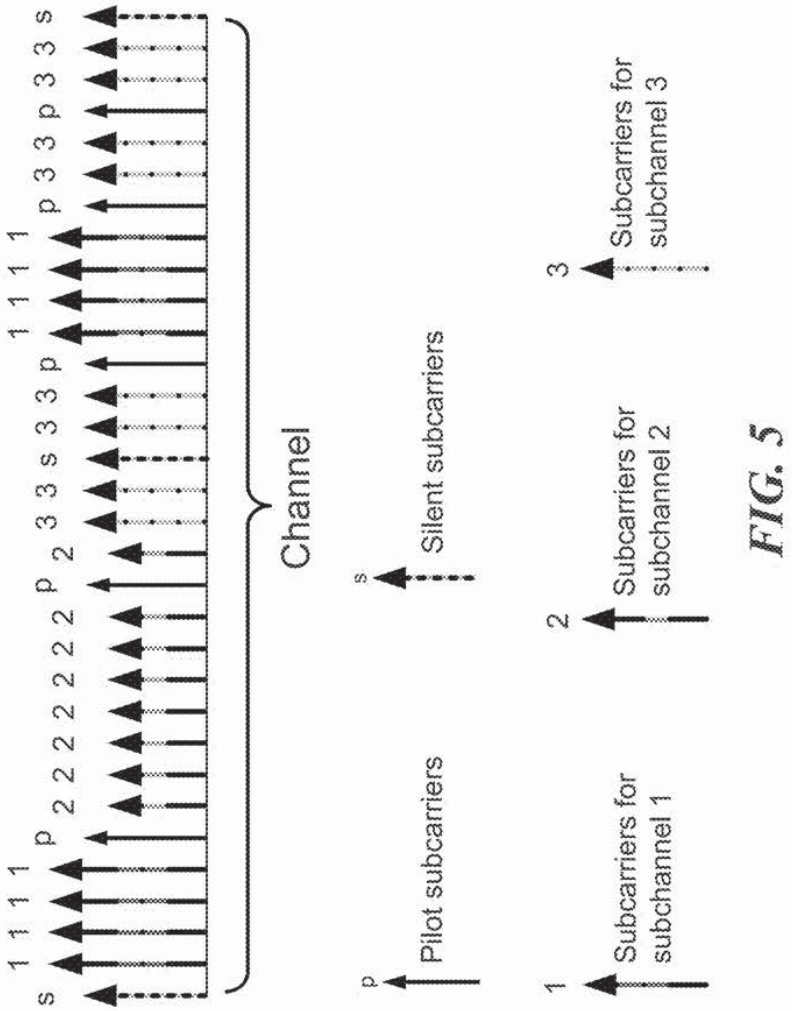

s 1 1 1 1 p 2 2 2 2 2 2 2 2 p 3 3 s 3 3 p 1 1 1 1 p 3 3 p 3 3 s
Channel
p Pilot subcarriers
s Silent subcarriers
1 Subcarriers for subchannel 1
2 Subcarriers for subchannel 2
3 Subcarriers for subchannel 3

FIG. 5

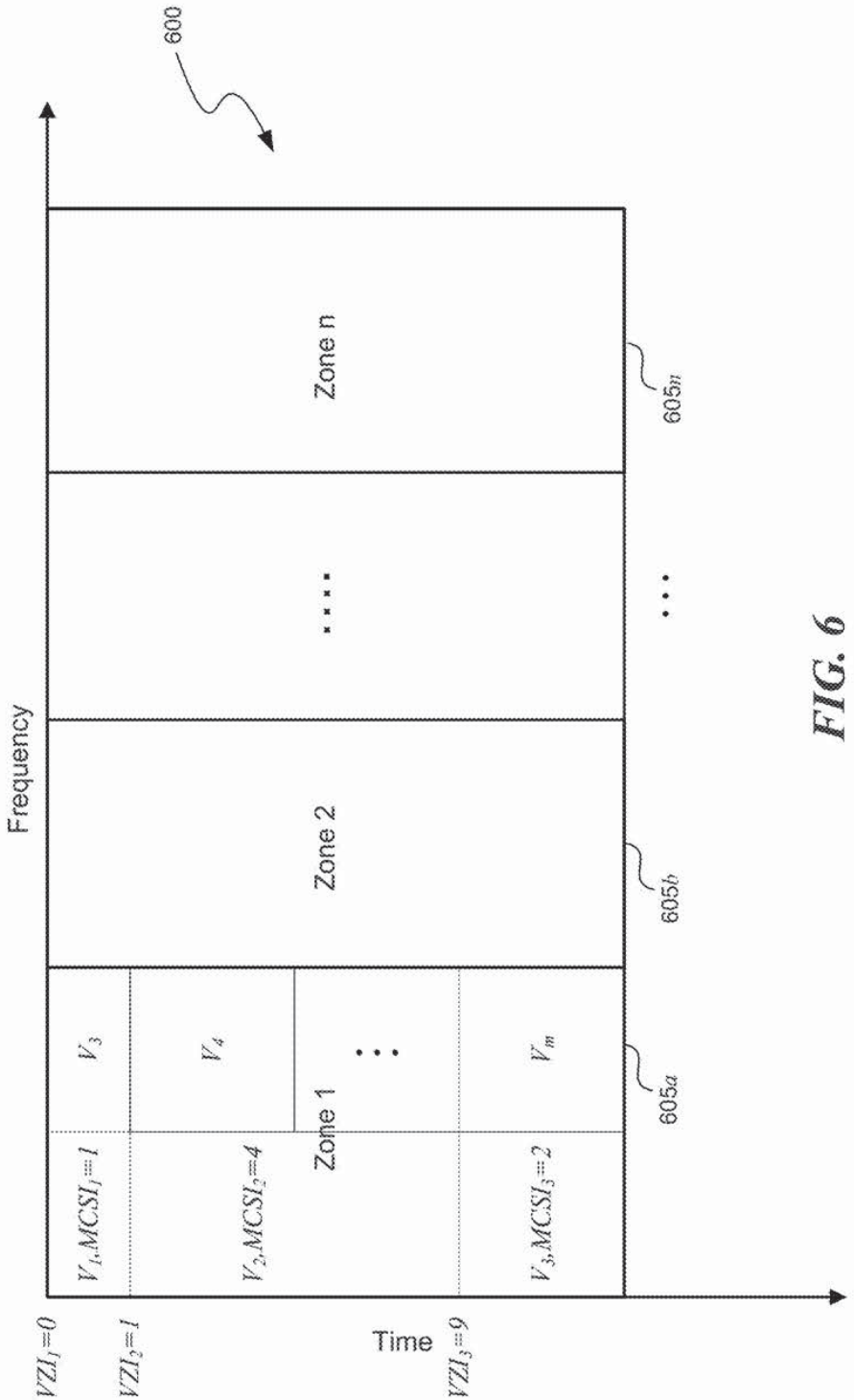

600
Frequency
Time
Zone n
Zone 2
Zone 1
605n
605b
605a
V3
V4
Vm
V1,MCSI1=1
V2,MCSI2=4
V3,MCSI3=2
VZI1=0
VZI2=1
VZI3=9

FIG. 6

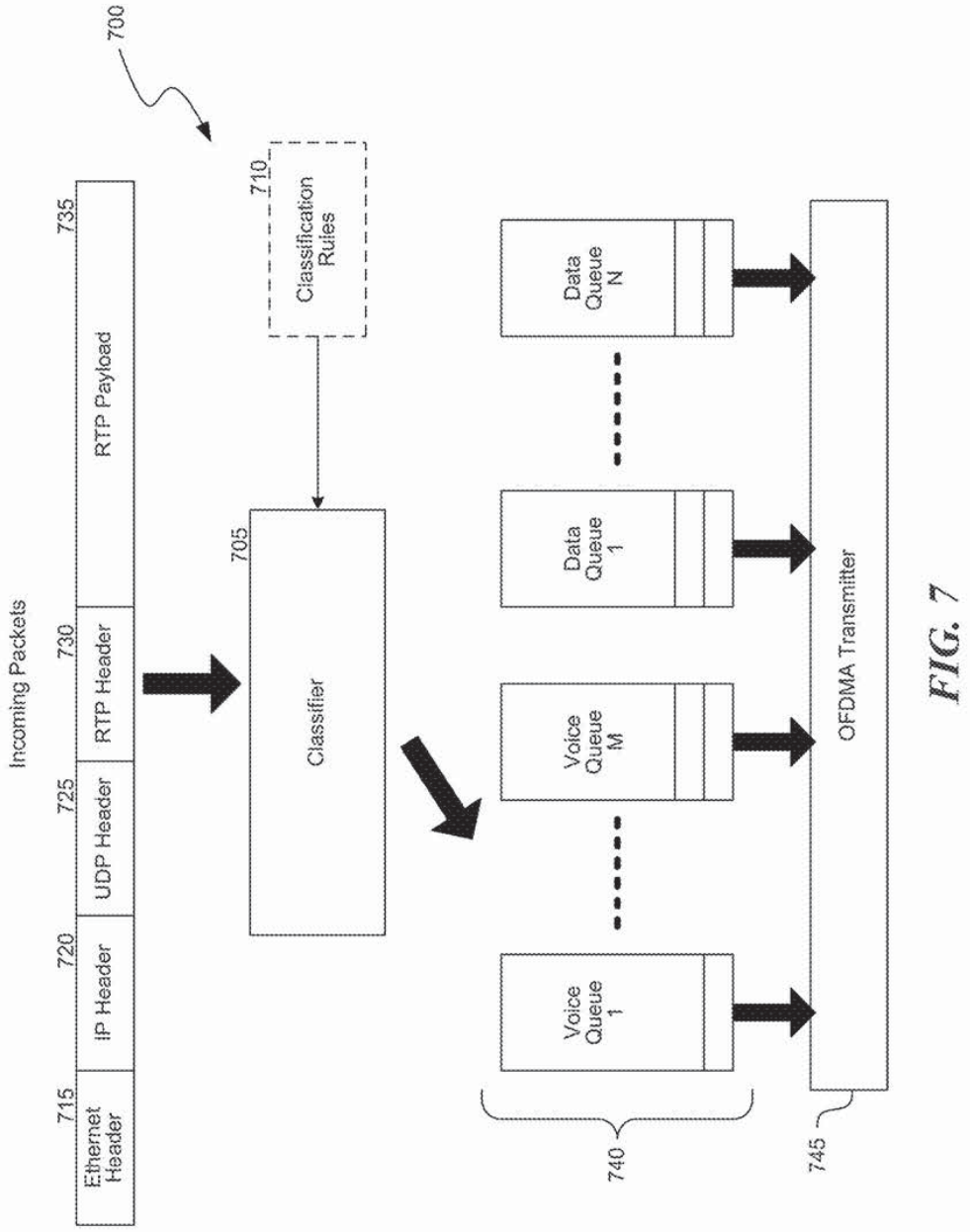

700
710
Classification Rules
735
RTP Payload
730
RTP Header
725
UDP Header
720
IP Header
715
Ethernet Header
Incoming Packets
705
Classifier
Data Queue N
Data Queue 1
Voice Queue M
Voice Queue 1
740
OFDMA Transmitter
745

FIG. 7

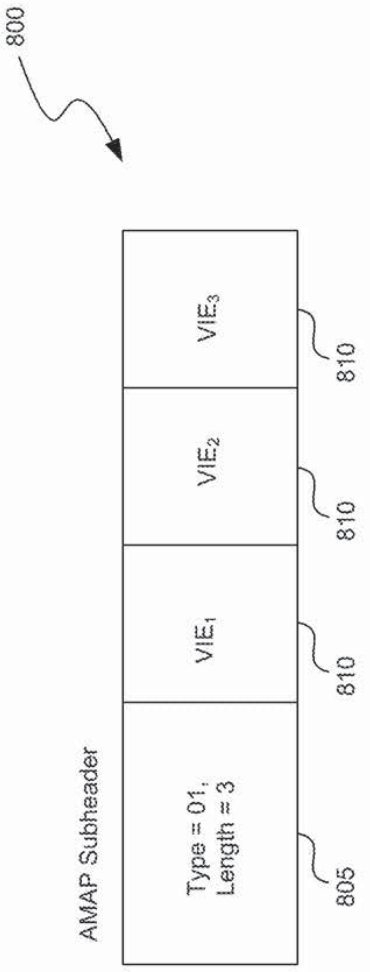

800
AMAP Subheader
Type = 01,
Length = 3
805
VIE1
810
VIE2
810
VIE3
810

FIG. 8A

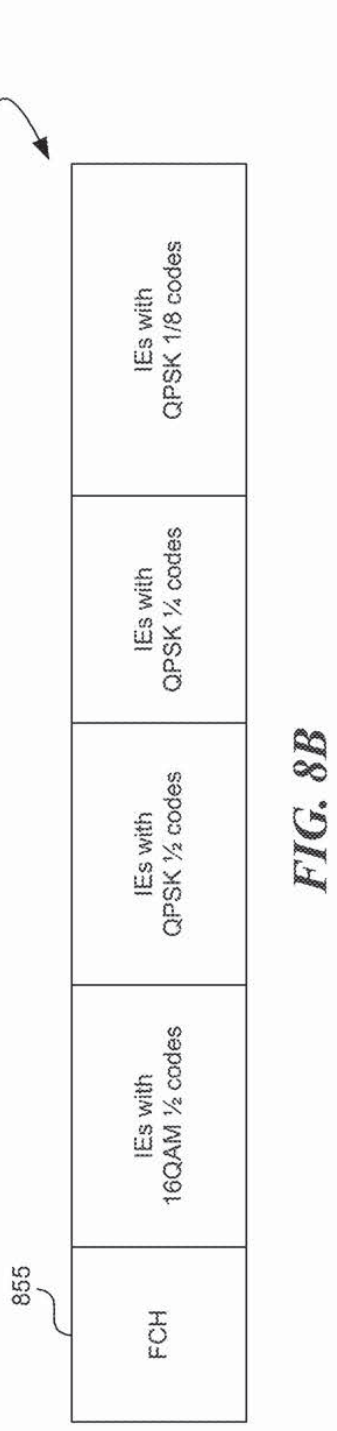

850
FCH
855
IEs with
16QAM ½ codes
IEs with
QPSK ½ codes
IEs with
QPSK ¼ codes
IEs with
QPSK 1/8 codes

FIG. 8B

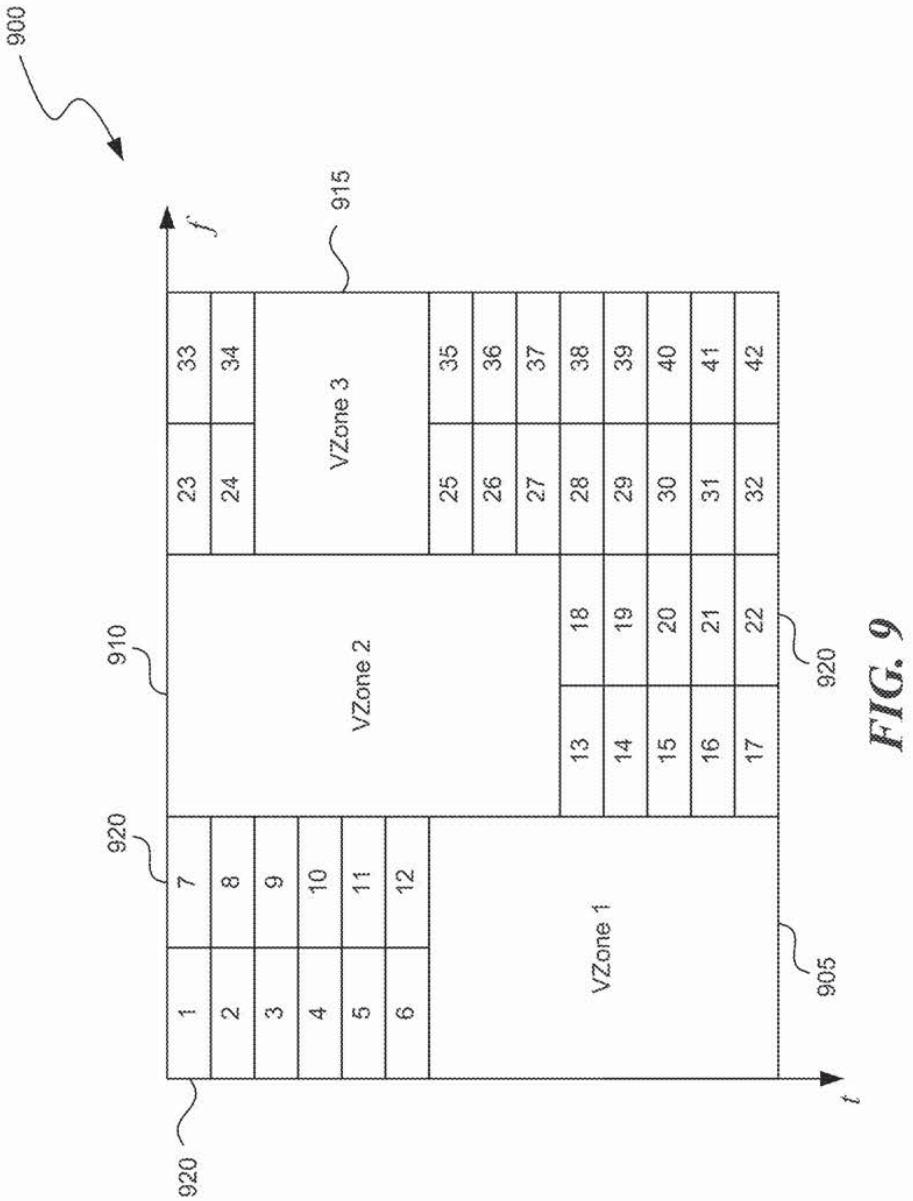

900
915
f
VZone 3
VZone 2
VZone 1
910
920
905
t
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
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41
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FIG. 9

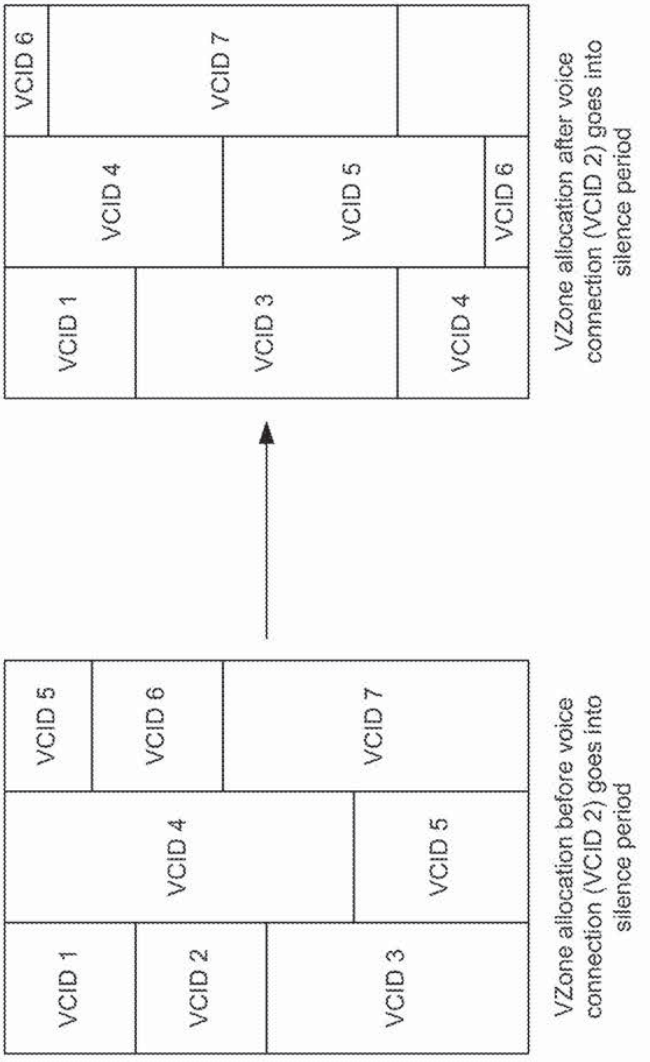

VCID 5
VCID 6
VCID 7
VCID 4
VCID 5
VCID 1
VCID 2
VCID 3
VZone allocation before voice connection (VCID 2) goes into silence period
VCID 6
VCID 7
VCID 4
VCID 5
VCID 6
VCID 1
VCID 3
VCID 4
VZone allocation after voice connection (VCID 2) goes into silence period

FIG. 10A

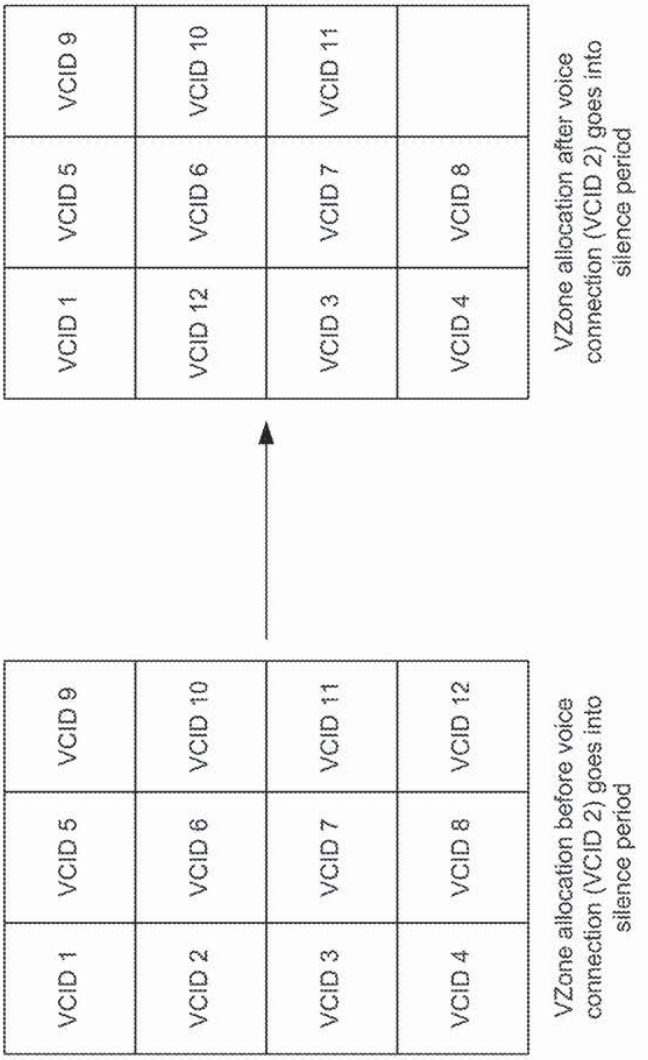

VCID 1
VCID 5
VCID 9
VCID 2
VCID 6
VCID 10
VCID 3
VCID 7
VCID 11
VCID 4
VCID 8
VCID 12
VZone allocation before voice connection (VCID 2) goes into silence period
VCID 1
VCID 5
VCID 9
VCID 12
VCID 6
VCID 10
VCID 3
VCID 7
VCID 11
VCID 4
VCID 8
VZone allocation after voice connection (VCID 2) goes into silence period

FIG. 10B

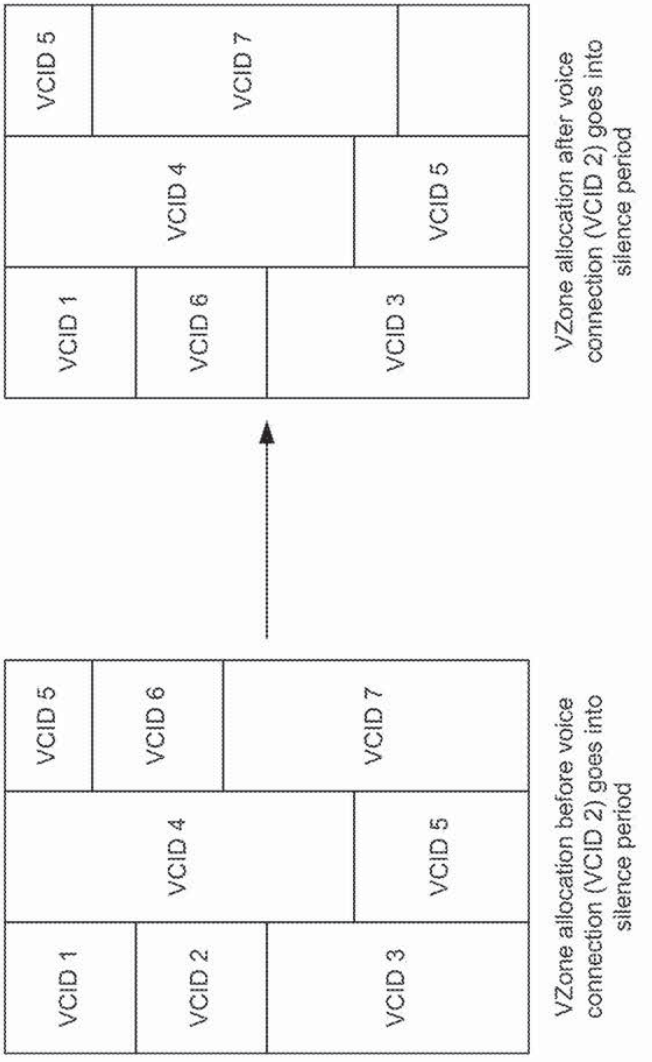

VCID 1
VCID 2
VCID 3
VCID 4
VCID 5
VCID 6
VCID 7
VZone allocation before voice connection (VCID 2) goes into silence period
VCID 1
VCID 6
VCID 3
VCID 4
VCID 5
VCID 5
VCID 7
VZone allocation after voice connection (VCID 2) goes into silence period

FIG. 10C

METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of, and incorporates by reference in its entirety, U.S. patent application Ser. No. 14/720,554, filed on May 22, 2015, which is a continuation of U.S. patent application Ser. No. 14/248,243, filed on Apr. 8, 2014, now U.S. Pat. No. 9,042,337, which is a continuation of U.S. patent application Ser. No. 13/115,055, filed on May 24, 2011, now U.S. Pat. No. 8,693,430, which is a continuation of U.S. patent application Ser. No. 11/908,257, filed on Jul. 14, 2008, now U.S. Pat. No. 7,948,944, which is a national stage application of PCT/US06/38149, filed Sep. 28, 2006, which claims the benefit of U.S. Provisional Patent Application No. 60/721,451, filed on Sep. 28, 2005.

This application is related to, and incorporates by reference in its entirety, U.S. patent application Ser. No. 13/631,735, filed on Sep. 28, 2012, now U.S. Pat. No. 8,634,376.

TECHNICAL FIELD

The disclosed technology relates, in general, to wireless communication and, in particular, to multi-carrier packet communication networks.

BACKGROUND

Bandwidth efficiency is one of the most important system performance factors for wireless communication systems. In packet based data communication, where the traffic has a bursty and irregular pattern, application payloads are typically of different sizes and with different quality of service (QoS) requirements. In order to accommodate different applications, a wireless communication system should be able to provide a high degree of flexibility. However, in order to support such flexibility, additional overhead is usually required. For example, in a wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile station to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. The MAC scheduler allocates wireless airlink resources to these connections. Special scheduling messages, DL-MAP and UL-MAP, are utilized to broadcast the scheduling decisions to the mobile stations.

In the MAP scheduling message defined by IEEE802.16, there is significant control overhead. For example, each connection is identified by a 16 bits connection ID (CID). The CID is included in the MAP message to identify the mobile station. The maximum number of connections that a system can support is therefore 65,536. Each mobile station has at least two management connections for control and management messages and a various number of traffic connections for application data traffic. As another example, each connection includes the identification of an airlink resource that can correspond to any time/frequency region that is allocated for communication. The resource allocation is identified in the time domain scale with a start symbol offset (8 bits) and a symbol length (7 bits) and in the frequency domain scale with a start logical subchannel offset (6 bits) and a number of allocated subchannels (6 bits). Due to the fact that different applications have different resource requirements, the allocated resource region is irregular from connection to connection. As a still further example, the modulation and coding scheme for each connection is identified by a 4-bit MCS code, identified as either a downlink interval usage code (DIUC) or an uplink interval usage code (UIUC). Another 2 bits are used to indicate the coding repetition in addition to 3 bits for power control. Overall, the overhead of a MAP message is 52 bits. For applications such as voice-over-IP (VoIP), the payload of an 8 Kbps voice codec is 20 bytes in every 20 ms. The overhead of the MAP message alone can therefore account for as much as 32.5% of the overall data communication, thereby resulting in a relatively low spectral efficiency. It would therefore be beneficial to reduce the overhead in a multi-carrier packet communication system to improve the spectral efficiency of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates the coverage of a wireless communication network that is comprised of a plurality of cells.

FIG. **2** is a block diagram of a receiver and a transmitter, such as might be used in a multi-carrier wireless communication network.

FIG. **3** is a block diagram depicting a division of communication capacity in a physical media resource.

FIG. **4** is a graphical depiction of the relationship between a sampling frequency, a channel bandwidth, and usable subcarriers in a channel.

FIG. **5** is a graphical depiction of the structure of a multi-carrier signal in the frequency domain.

FIG. **6** is a block diagram of a time-frequency resource utilized by a wireless communication network.

FIG. **7** is a block diagram of a classifier for classifying received packets by application, QoS, or other factor.

FIGS. **8**A and **8**B are block diagrams of representative control message formats.

FIG. **9** is a block diagram of a special resource zone with unit sequence defined in time-first order.

FIGS. **10**A-**10**C are block diagrams illustrating the real-located of resources within a resource zone.

DETAILED DESCRIPTION

A system and method for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information.

In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. An application connection-specific identifier (ACID) may also be assigned to a packet stream. Both measures reduce the overhead associated with managing multiple application streams in a communication network.

In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead. The control messages may include

information such as the packet destination, the modulation and coding method, and the airlink resource used. Control messages of the same application type or subtype, modulation and coding scheme, or other parameter may be grouped together for efficiency.

While the following discussion contemplates the application of the disclosed technology to an Orthogonal Frequency Division Multiple Access (OFDMA) system, those skilled in the art will appreciate that the technology can be applied to other system formats such as Code Division Multiple Access (CDMA), Multi-Carrier Code Division Multiple Access (MC-CDMA), or others. Without loss of generality, OFDMA is therefore only used as an example to illustrate the present technology. In addition, the following discussion uses voice-over-IP as a representative application to which the disclosed technology can be applied. The disclosed technology is equally applicable to other applications including, but not limited to, audio and video.

The following description provides specific details for a thorough understanding of, and enabling description for, various embodiments of the technology. One skilled in the art will understand that the technology may be practiced without these details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the technology. It is intended that the terminology used in the description presented below be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain embodiments of the technology. Although certain terms may be emphasized below, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section.

I. Wireless Communication Network

FIG. **1** is a representative diagram of a wireless communication network **100** that services a geographic region. The geographic region is divided into a plurality of cells **105**, and wireless coverage is provided in each cell by a base station (BS) **110**. One or more mobile devices (not shown) may be fixed or may roam within the geographic region covered by the network. The mobile devices are used as an interface between users and the network. Each base station is connected to the backbone of the network, usually by a dedicated link. A base station serves as a focal point to transmit information to and receive information from the mobile devices within the cell that it serves by radio signals. Note that if a cell is divided into sectors, from a system engineering point of view each sector can be considered as a cell. In this context, the terms "cell" and "sector" are interchangeable.

In a wireless communication system with base stations and mobile devices, the transmission from a base station to a mobile device is called a downlink (DL) and the transmission from a mobile device to a base station is called an uplink (UL). FIG. **2** is a block diagram of a representative transmitter **200** and receiver **205** that may be used in base stations and mobile devices to implement a wireless communication link. The transmitter comprises a channel encoding and modulation component **210**, which applies data bit randomization, forward error correction (FEC) encoding, interleaving, and modulation of an input data signal. The channel encoding and modulation component is coupled to a subchannel and symbol construction component **215**, an inverse fast Fourier transform (IFFT) component **220**, and a radio transmitter component **225**. Those skilled in the art will appreciate that these components construct and transmit a communication signal containing the data that is input to the transmitter **200**. Other forms of transmitter may, of course, be used depending on the requirements of the communication network.

The receiver **205** comprises a reception component **230**, a frame and synchronization component **235**, a fast Fourier transform component **240**, a frequency, timing, and channel estimation component **245**, a subchannel demodulation component **250**, and a channel decoding component **255**. The channel decoding component de-interleaves, decodes, and derandomizes a signal that is received by the receiver. The receiver recovers data from the signal and outputs the data for use by the mobile device or base station. Other forms of receiver may, of course, be used depending on the requirements of the communication network.

FIG. **3** is a block diagram depicting the division of communication capacity in a physical media resource **300** (e.g., radio or cable) into frequency and time domains. The frequency is divided into two or more subchannels **305**, represented in the diagram as subchannels 1, 2, . . . m. Time is divided into two or more time slots **310**, represented in the diagram as time slots 1, 2, . . . n. The canonical division of the resource by both time and frequency provides a high degree of flexibility and fine granularity for resource sharing between multiple applications or multiple users of the resource.

FIG. **4** is a block diagram representing the relationship between the bandwidth of a given channel and the number of usable subcarriers within that channel. A multi-carrier signal in the frequency domain is made up of subcarriers. In FIG. **4**, the sampling frequency is represented by the variable f_s, the bandwidth of the channel is represented by the variable B_{ch}, and the effective bandwidth by the variable B_{eff} (where the effective bandwidth is a percentage of the channel bandwidth). The number of usable subcarriers within the channel is defined by the following equation:

$$\#\_usable\_subcarriers = \frac{B_{eff}}{f_s} \times N_{fft}$$

Where N_{fft} is the length of the fast Fourier transform. Those skilled in the art will appreciate that for a given bandwidth of a spectral band or channel (B_{ch}), the number of usable subcarriers is finite and limited, and depends on the size of the FFT, the sampling frequency (f_s), and the effective bandwidth (B_{eff}) in accordance with equation 1.

FIG. **5** is a signal diagram depicting the various subcarriers and subchannels that are contained within a given channel. There are three types of subcarriers: (1) data subcarriers, which carry information data; (2) pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers, and which are used for assisting system functions such as estimation of system parameters; and (3) silent subcarriers, which have no energy and are used for guard bands and as a DC carrier. The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The subcarriers forming one subchannel may or may not be adjacent to each other. Each mobile device may use some or all of the subchannels.

A multi-carrier signal in the time domain is generally made up of time frames, time slots, and OFDM symbols. A frame consists of a number of time slots, and each time slot is comprised of one or more OFDM symbols. The OFDM time domain waveform is generated by applying an inverse-

fast-Fourier-transform (IFFT) to the OFDM symbols in the frequency domain. A copy of the last portion of the time domain waveform, known as the cyclic prefix (CP), is inserted in the beginning of the waveform itself to form an OFDM symbol.

In some embodiments, a mapper such as the subchannel and symbol construction component **215** in FIG. **2** is designed to map the logical frequency/subcarrier and OFDM symbol indices seen by upper layer facilities, such as the MAC resource scheduler or the coding and modulation modules, to the actual physical subcarrier and OFDM symbol indices. A contiguous time-frequency area before the mapping may be actually discontinuous after the mapping, and vice versa. On the other hand, in a special case, the mapping may be a "null process", which maintains the same time and frequency indices before and after the mapping. The mapping process may change from time slot to time slot, from frame to frame, or from cell to cell. Without loss of generality, the terms "resource", "airlink resource", and "time-frequency resource" as used herein may refer to either the time-frequency resource before such mapping or after such mapping.

II. Airlink Resource Zones

Various technologies are now described that may be utilized in conjunction with the wireless communication network **100** in order to reduce the amount of control overhead associated with the use of system resources. By reducing the control overhead, greater spectral efficiency is achieved allowing the system to, among other benefits, maximize the amount of simultaneously supported communications.

FIG. **6** is a map of a time-frequency resource **600** that is allocated for use by the wireless communication network **100**. As described above, in a typical wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile device to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. As a result, various applications carried in packet streams may be spread throughout the available time-frequency resource. To overcome the inefficiencies associated with maintaining this mapping, FIG. **6** depicts an alternative way of managing multiple packet streams. The time-frequency resource **600** may be divided into one or more zones **605***a*, **605***b*, . . . **605***n*. Each of the zones **605***a*, **605***b*, . . . **605***n* is associated with a particular type of application. For example, zone **605***a* may be associated with voice applications (e.g., VoIP), zone **605***b* may be associated with video applications, and so on. As will be described in additional detail below, by grouping like applications together the amount of control overhead in MAC headers is reduced. Zones may be dynamically allocated, modified, or terminated by the system.

When applications of a similar type are grouped together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a time-frequency segment can be achieved. In some embodiments, the identification of the time-frequency segment associated with a particular packet stream can be indicated by the starting time-frequency coordinate and the ending time-frequency coordinate relative to the starting point of the zone. The granularity in the time coordinates can be one or multiple OFDM symbols, and that in the frequency coordinates can be one or multiple subcarriers. If the time-frequency resource is divided into two or more zones, the amount of control information necessary to map to a location relative to the starting point of the zone may be significantly less than the amount of information necessary to map to an arbitrary starting and ending coordinate in the entire time-frequency resource.

Within each zone **605***a*, **605***b*, . . . **605***n*, the time-frequency resource may be further divided in accordance with certain rules to accommodate multiple packet streams $V_1, V_2, \ldots V_m$. For example, as depicted in FIG. **6**, zone **605***a* is divided into multiple columns and the packet streams are arranged from top down in each column and from left to right across the columns. The width of each column can be a certain number of subcarriers. Each packet stream $V_1, V_2, \ldots V_m$ may be associated with an application. For example, V_1 is the resource segment to be used for the first voice packet stream, V_2 is the resource segment to be used for the second voice packet stream, etc. While the zone **605***a* is divided and the packet streams numbered starting at an origin of the zone, it will be appreciated that the division of the time-frequency resource in accordance with certain rules may start at other origin locations within the zone as well. Segments within each zone may be dynamically allocated by the system as requested and released by the system when expressly or automatically terminated.

When the zones are further subdivided into time-frequency segments in accordance with certain rules, a mapping of packet streams to segment may be achieved using a one-dimensional offset with respect to the origin of the zone rather than the two-dimensional (i.e. starting time-frequency coordinate and ending time-frequency coordinate relative to the starting point of the zone) mapping method discussed above. Calculation of such an offset may require knowledge of a modulation and coding scheme that is associated with a particular packet stream. For example, Table 1 below sets forth representative modulation and forward-error correction (FEC) coding schemes (MCS) that may be used for voice packet streams under various channel conditions.

TABLE 1

MCSI	Modulation	Coding rate	Information bits	Raw symbols	Units
1	16QAM	½	160	80	1
2	QPSK	½	160	160	2
3	QPSK	¼	160	320	4
4	QPSK	⅛	160	640	8

In some embodiments, the MCS may be selected to utilize modular resources. For example, as illustrated in Table 1, 80 raw modulation symbols are needed to transmit 160 information bits using 16QAM modulation and rate-1/2 coding, the highest available MCS in the table. The resource utilized by this highest MCS is called a basic resource unit ("Unit"), i.e., 80 raw symbols in this example. The resource utilized by other MCS is simply an integer multiple of the basic unit. For example, four units are required to transmit the same number of information bits using QPSK modulation with rate-1/4 coding. The MCS index (MCSI) conveys the information about modulation and coding schemes. For a known vocoder, MCSI also implies the number of AMC resource units required for a voice packet. Those skilled in the art will appreciate that coding and signal repetition can be combined to provide lower coding rates. For example, rate-1/8 coding can be realized by a concatenation of rate-1/2 coding and 4-time repetition.

The decision process for selecting the proper MCS of a packet can vary by application. In some embodiments, the process for voice packets can be more conservative than that for general data packets due to the QoS requirements of the voice applications. For example, when the signal to inter-

ference noise ratio (SINR) is used as a threshold for selecting the MCS, the threshold value for voice packets is set higher than that for general data packets. For example, the SINR threshold of QPSK with rate-1/2 coding for voice packets is 12 dB, while that for general data packets is 10 dB.

If a MCS from Table 1 is selected for each packet stream contained in a particular zone, the offset to a segment representing a particular packet stream may be easily calculated. For example, an index VZI_1, VZI_2, . . . VZI_m is shown at the origin of each segment that is contained in the zone **605***a*. The index for any selected packet stream is defined as the sum of all basic resource units associated with each packet stream preceding the selected packet stream, with an optional adjustment depending on the location where the division of the time-frequency resource is started (typically no adjustment is required since the division starts at the origin of the zone). For example, the location index for the first voice packet stream is $VZI_1=0$ since it starts at the origin of the zone **605***a*. The first packet stream has an MCS of 1, which implies that one basic resource unit is used. As a result, the index for the second voice packet stream is $VZI_2=1$. The second packet stream has an MCS of 4, which implies that eight basic resource units are used. As a result, the index for the third voice packet stream is $VZI_3=9$, arrived by summing the basic resource units used for the preceding first and second packet streams.

Using basic resource units as the granularity of a location offset to the packet stream reduces the number of bits required to represent its location with the zone **605***a*. For example, to support a maximum of 64 VoIP calls in a cell, a maximum of 64×8=512 units might be used, assuming that every voice packet is transmitted using the lowest MCS. Therefore, a 9-bit number is sufficient to represent a VZI. In practice, different voice packets may be transmitted using different MCSs, some with MCSI=1, some with MCSI=4, so on so forth. According to statistics, a shorter bit-length than the maximum needed, for example 8 bits, may be used for VZI for practical purpose.

In some embodiments, control information necessary to map a packet stream to a resource segment may be still further reduced. In the case where an MCS is used with packet streams that are located sequentially in the zone. The index of a packet can be inferred from the MCSI of the packets located before the subject packet. For example, if the first voice packet stream uses $MCSI_1=1$, 16QAM with 1/2 coding, and the second voice packet stream uses $MCSI_2=4$, QPSK with 1/8 coding, then the first two voice packet streams occupy 1+8=9 units, and the starting location of the third voice packet stream is the 9th unit. Rather than encode the index for each packet stream in the control information, the index can be omitted in the control message and the offset from the origin of the zone calculated as necessary.

Allocation of the time-frequency resource **600** can be carried out in a variety of ways. In some embodiments, an application zone may contain all subcarriers of one or multiple OFDM symbols or time slots. In some embodiments, the definition of an application zone, such as the location and size of the zone, may be different from cell-to-cell **105**. In some embodiments, in order to avoid inter-cell interference the zones of similar applications are allocated at different locations in neighboring cells. For example, voice applications may be located at a lower frequency range in the time-frequency resource in one cell, and at a higher frequency range in the time-frequency range in an adjacent cell. In some embodiments, the system allocates a fixed amount of resource to each voice connection. The system uses AMC and matches it with adaptive multi-rate (AMR) voice coding to improve the voice quality. Moreover, unused resources in one application zone may be allocated for other applications.

In a system with one or multiple application zones, the remaining resource unused by the application zones can be treated as a special resource zone. The special resource zone may be irregular in shape. For example, FIG. **9** depicts a time-frequency resource **900** having three defined zones **905**, **910**, and **915**. The remaining resource area that is shaded in the figure represents the special resource zone. The MAC scheduler may track the time-frequency resources in this special zone and broadcast the resource allocation in a special zone MAP message. In some embodiments, the special zone MAP message explicitly identifies the resource zone, for example using the time and frequency coordinates of a resource block. A mobile device can identify its own resource by decoding the MAP message.

In some embodiments, both the base station and the mobile device share the configuration information of the special resource zone, and view the special zone as a contiguous resource zone. The MAP message only includes the resource allocation information in the special resource zone, using connection ID (described below), resource identification parameters and MCS index.

In some embodiments, the MAP message can be further compressed if the special resource zone is further divided into a sequence of pre-defined resource units. For example, the shaded area in FIG. **9** has been further divided into forty-two resource units **920**, first numbered sequentially along the time axis and then continuing in columns along the frequency axis. If the size of each resource unit is predefined, the location within the special resource zone may be determined based on a mapping to a sequence number.

III. Application Connection IDs

When a mobile device enters a wireless network, it is first assigned a basic connection identification (BCID) for each direction of the wireless connection: downlink and uplink. A BCID can be used for control messages or generic (unclassified) application connections. The BCID for downlink may or may not be the same as that of the uplink.

In some embodiments, a classification of packet streams may be performed by the system. FIG. **7** is a block diagram of a system component **700** for receiving IP packets and sorting the received packets into various streams. The system component **700** includes a classifier **705** having associated classification rules **710**. The classifier receives incoming packets, each packet having various header information such as an Ethernet header **715**, an IP header **720**, a UDP header **725**, an RTP header **730** and an RTP payload **735**. The packets are classified by the classifier **705** and output into different application data queues **740** where they will subsequently be transmitted by an OFDMA transmitter **745**.

The classifier **705** is able to classify the packets based on application type, quality of service (QoS) requirement, or other properties. For example, packets from a voice application stream are identified based on a special value in the type of service (ToS) field in the IP header **720** of the packets. A new combination of RTP/UDP/IP headers with the special IP ToS field value indicates a new voice application stream. Such a new stream is identified by peeking into voice session setup protocol messages, such as session initiation protocol (SIP). The classification performed by the classifier is based on one or more classification rules **710**. The classification rules can be configured statically or dynamically by a control process. Each classification rule is

defined using parameters, such as application type, QoS parameters, and other properties that may be determined from the received packets.

In some embodiments, the incoming packets may also be assigned an application connection-specific identifier (ACID) in addition to or in lieu of a BCID. Each ACID can be assigned to a corresponding packet stream. For example, an ACID can be assigned to voice packets that together make up a voice application. When an ACID is assigned to a voice application, the ACID may also be referred to as a voice connection ID (VCID). As another example, an ACID can be assigned to a packet stream that requires a particular QoS. Furthermore, an application packet stream can be further classified into different sub-types, based on certain properties of that application. For example, voice applications can be further classified into different sub-types based on the voice source coding (vocoder) methods (e.g., G.711 and G.729A). When further classified in this matter, the sub-types may each be assigned their own ACID. For certain multi-casting applications, an ACID may also be shared by multiple base stations or mobile devices.

Once established, the connection IDs, including BCIDs and ACIDs, are disseminated, through broadcasting messages for example, to the corresponding base station(s) and mobile device(s) for proper packet transmission and reception. As was previously discussed, the medium access control (MAC) scheduler may allocate specific zones of airlink resources for certain types of packet streams.

A connection ID is released once the wireless system determines that there is no need to continue the connection. For example, a voice connection and its VCID are released once the system detects deactivation of the voice stream. In some embodiments, the voice connection is deactivated if the voice session disconnect is detected through snooping SIP signaling. In some embodiments, the voice connection is released if there is no voice packet activity on the connection for a certain period of time.

In some embodiments, the same bit length is used in different types of connections IDs, including BCIDs and ACIDs. In some embodiments, different types of connection IDs may have different bit lengths. For example, in a typical implementation for voice applications, a BCID may be 16-bits to accommodate a large number of mobile devices and unclassified applications, while a VCID is 6-bits to accommodate up to 64 simultaneous voice connections in a cell. A shorter ACID length is beneficial for reducing control overhead, especially when an application utilizes many small data packets, such as VoIP packets.

In some embodiments, an ACID is further augmented by other properties of the utilized airlink resources, such as time or frequency indices, to identify an application connection. This can be used to further reduce ACID bit length or to increase the maximum number of accommodated application connections given a certain ACID bit length. For example, a voice codec generates voice application data periodically. The allocation period is usually a multiple of the airlink frame duration. In this case, the airlink frame number can be combined with a VCID to identify a voice connection. For example, the voice codec of G.723.1 generates a voice frame once every 30 milliseconds. The MAC scheduler allocates airlink resource to such a voice connection once every 30 ms. In a wireless cellular system using 5 ms frame duration, a single VCID can be shared by 6 voice streams, each associated with a different frame number to uniquely identify a voice connection.

IV. Control Messages

When airlink resource zones or application-specific IDs are utilized by the system, various improved control messages, often called Information Elements (IEs), may be constructed to facilitate the control process and minimize the control overhead. Various control message improvements are described herein.

In some embodiments, the IE is sent prior to transmitting an application packet to indicate information associated with the packet, such as the packet destination, the modulation and coding method, and the airlink resource used. For example, the IE for a voice packet may include the VCID (indicative of the packet destination), the MCSI (encoding scheme), and the VZI (index to location fo the packet stream within the airlink resource). In some embodiments, the VCID is 6 bits, the MCSI is 2 bits, and the VZI is 8 bits, thereby resulting in a 2-byte IE overhead for each voice packet. Alternatively, the IE for a voice packet may include only the VCID and the MCSI, with the VZI inferred from the MCSIs of previous packet streams in the airlink resource as described above. When using only the VCID and MCSI, the IE overhead for each voice packet is reduced to only 1 byte. Additional control information, such as power control information, can be added to the IE with additional bit fields. The reduction in control bits improves the overall bandwidth efficiency of the wireless communication network.

In some embodiments, a base station sends the IE before a downlink packet to inform the mobile device for proper reception of the packet, and the base station sends the IE before an uplink packet to inform the mobile device for proper transmission of the packet. The downlink and uplink packet IEs may be separately grouped together. The IEs may be broadcasted or multi-casted to corresponding destinations.

In some embodiments, the IEs of the same application type or subtype may be grouped together. A special field, called an Application MAP (AMAP) subheader, for a specific application type, may be added to the IE. The subheader may indicate the application type and the length of the IE group. FIG. **8**A is a block diagram of a representative IE **800** with an AMAP subheader **805**, in this case used for voice applications. The AMAP subheader **805** includes a type variable and a length variable. As depicted in FIG. **8**A, type=01 indicates that the application type is voice. Length=3 indicates that the subheader is followed by three voice IEs. The remainder of the IE contains the three voice IEs **810***a*, **810***b*, and **810***c*. For example, if the AMAP subheader was associated with streams in the zone **605***a* depicted in FIG. **6**, then voice IE **810***a* would pertain to packet stream V_1, voice IE **810***b* would pertain to packet stream V_2, and voice IE **810***c* would pertain to packet stream V_3. Those skilled in the art will appreciate that the although text is used to indicate the contents of the IE in FIG. **8**A, in an actual implementation the text would be replaced by appropriately coded information.

In some embodiments, the IEs for all packets that are transmitted with the same modulation and coding schemes (MCS) are grouped together for efficiency. FIG. **8**B is a block diagram of a block **850** of IEs that are grouped by MCS. A frame control header (FCH) **855** or other control message is transmitted prior to the block to indicate the length and the MCS used for each segment of the block. In some embodiments, adaptive modulation and coding (AMC) is used for the transmission of the IE's. A special rule, which is known to both base stations and mobile devices, can be used to determine the IE MCS, based on the MCS of its corresponding packet for proper reception of the IE. In some

embodiments, the MCS for an IE is maintained the same as that of its corresponding application packet. In some embodiments, the MCS for an IE is one level more conservative than that of its corresponding packet. For example, if the MCSI for a packet is 2 (QPSK with rate-1/2 coding), then the MCSI for its IE is 3 (QPSK with rate-1/4 coding).

V. Voice Activity Detection

Typical voice conversations contain approximately 50 percent silence. In order to take advantage of the fact that about half of the time data does not need to be transmitted at the same rate as when a user is speaking, the system may rely upon detecting the period of silence and reducing the effective data transfer rate during that period. The silence period in conversation is detected by a vocoder using technologies such as Voice Activity Detection (VAD). Voice packets are only generated when voice activity is detected. During the silence period, the voice packet data rate is greatly reduced.

In addition to reducing the voice packet data rate during periods of silence, the bandwidth allocation for the voice connection may also be reduced. The MAC scheduler at the base station may use the indication of voice activity to adjust the bandwidth allocation for the voice connection. In the uplink direction, the mobile device sends a special MAC message once a VAD indication is received from its vocoder. The MAC message indicates to the base station that the voice data rate is being temporarily reduced. When such an indication is received, the MAC scheduler can reduce the airlink resource allocated to the voice connection. Similarly, if the VAD indicates new voice activity, the mobile device notifies the base station using a MAC message and the original resource allocation is re-applied to the voice connection.

In the downlink direction, if there is no voice packet to be transmitted over a voice connection, the MAC scheduler allocates the resource to other voice connections. As a consequence, a resource block previous allocated for the connection in a particular zone may become vacant. Several methods can be used to deal with such fragmentation in the zone.

In some embodiments, the MAC scheduler at the base station reallocates the resource with the objective of minimizing the impact to other voice connections, such as their adaptive modulation and coding processes.

In some embodiments, the MAC scheduler maintains the resource allocation of the other voice connections, and allocates the resource vacated by the silent voice connection to new voice connections or other application packets.

In some embodiments, the MAC scheduler moves all the subsequent allocations up to fill the resource gap. As shown in FIG. **10**A, once a voice connection, identified by VCID **2** enters a silent period, the other voice connections are moved by the MAC scheduler to occupy the resource vacated by VCID **2**.

In some embodiments, the MAC scheduler uses the last voice time-frequency resource in the same zone to fill the resource gap of a silent voice connection. FIG. **10**B illustrates such a case, when the MAC scheduler moves the last voice connection VCID **12** to occupy the resource allocation gap that is vacated by the voice connection VCID **2**.

In some embodiments, the MAC scheduler uses the last voice time-frequency resource that has the same coding and modulation scheme, and is contained in the same zone, to fill the resource gap. The resource gap that is introduced by such a replacement is then filled by the voice time-frequency resource that is subsequent to the voice time-frequency resource that was moved. As shown in FIG. **10**C, voice connection VCID **6** uses the same coding and modulation scheme as voice connection VCID **2**, and is the last connection having that scheme in the zone. When voice connection VCID **2** goes into a silent period, the MAC scheduler allocates the voice connection VCID **2** resource to voice connection VCID **6**. The MAC scheduler then moves resources after voice connection VCID **6**, specifically VCID **7** in FIG. **10**C, to occupy the resource allocation gap that is caused by moving voice connection VCID **6**.

The above detailed description of embodiments of the system is not intended to be exhaustive or to limit the system to the precise form disclosed above. While specific embodiments of, and examples for, the system are described above for illustrative purposes, various equivalent modifications are possible within the scope of the system, as those skilled in the relevant art will recognize. For example, while processes are presented in a given order, alternative embodiments may perform routines having steps in a different order, and some processes may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or subcombinations. Each of these processes may be implemented in a variety of different ways. Further any specific numbers noted herein are only examples: alternative implementations may employ differing values or ranges.

These and other changes can be made to the invention in light of the above Detailed Description. While the above description describes certain embodiments of the technology, and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Details of the system may vary considerably in its implementation details, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

We claim:

1. An operating method for a wireless network comprising at least a base station and a mobile station, the wireless network employing a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the method comprising:

assigning an identifier to the mobile station;

transmitting a signal containing information from the base station to the mobile station over a segment of time-frequency resource, the segment having a starting time-frequency coordinate and the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and

receiving by the mobile station the transmitted signal; and

recovering by the mobile station the information from the received signal based on the starting time-frequency coordinate and N in conjunction with the identifier assigned to the mobile station.

2. The method of claim 1, wherein the starting time-frequency coordinate indicates a starting OFDM symbol of the segment of time-frequency resource.

3. The method of claim 1, wherein the starting time-frequency coordinate indicates a starting subcarrier of the segment of time-frequency resource.

4. The method of claim 1, wherein the starting time-frequency coordinate indicates a starting group of subcarriers of the segment of time-frequency resource.

5. The method of claim 1, wherein modular coding is applied to the time-frequency resource units in the segment of time-frequency resource.

6. The method of claim 5, wherein a repetition coding is further applied to the time-frequence resource units.

7. A mobile device in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the mobile device configured to:

receive an identifier from a base station in a cell in which the mobile device is operating; and

receive a signal containing information from the base station over a segment of time-frequency resource, the segment having a starting time-frequency coordinate and the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and

recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier.

8. The mobile device of claim 7, wherein the starting time-frequency coordinate indicates a starting OFDM symbol of the segment of time-frequency resource.

9. The mobile device of claim 7, wherein the starting time-frequency coordinate indicates a starting subcarrier of the segment of time-frequency resource.

10. The mobile device of claim 7, wherein the starting time-frequency coordinate indicates a starting group of subcarriers of the segment of time-frequency resource.

11. The mobile device of claim 7, wherein modular coding is applied to the time-frequency resource units in the segment of time-frequency resource.

12. The mobile device of claim 11, wherein a repetition coding is further applied to the time-frequence resource units.

13. A base station in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the base station configured to:

provide an identifier to a mobile device in the cell;

allocate a segment of time-frequency resource for carrying information to the mobile device, the segment having a starting time-frequency coordinate and the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and

transmit a signal containing the information to the mobile device in a manner that allows the mobile device to recover the information using the starting time-frequency coordinate and N in conjunction with the provided identifier.

14. The base station of claim 13, wherein the starting time-frequency coordinate indicates a starting OFDM symbol of the segment of time-frequency resource.

15. The base station of claim 13, wherein the starting time-frequency coordinate indicates a starting subcarrier of the segment of time-frequency resource.

16. The base station of claim 13, wherein the starting time-frequency coordinate indicates a starting group of subcarriers of the segment of time-frequency resource.

17. The base station of claim 13, wherein modular coding is applied to the time-frequency resource units in the segment of time-frequency resource.

18. The base station of claim 17, wherein a repetition coding is further applied to the time-frequence resource units.

* * * * *

Exhibit 5

US010965512B2

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Li et al.

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(54) **METHOD AND APPARATUS USING CELL-SPECIFIC AND COMMON PILOT SUBCARRIERS IN MULTI-CARRIER, MULTI CELL WIRELESS COMMUNICATION NETWORKS**

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(58) **Field of Classification Search**
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See application file for complete search history.

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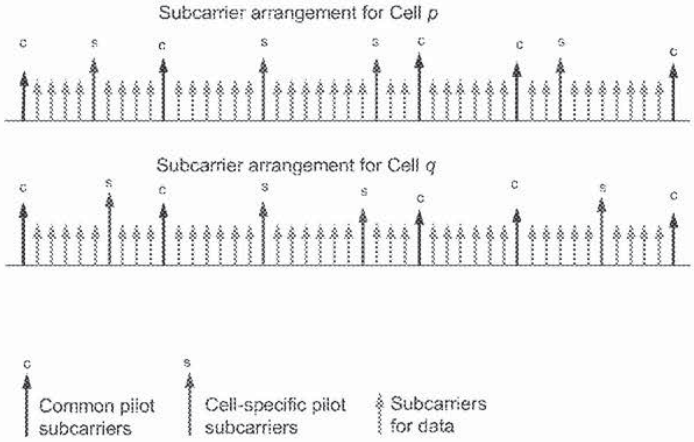
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(57) **ABSTRACT**

A multi-carrier cellular wireless network (**400**) employs base stations (**404**) that transmit two different groups of pilot subcarriers: (1) cell-specific pilot subcarriers, which are used by a receiver to extract information unique to each individual cell (**402**), and (2) common pilots subcarriers, which are designed to possess a set of characteristics common to all the base stations (**404**) of the system. The design criteria and transmission formats of the cell-specific and common pilot subcarriers are specified to enable a receiver to perform different system functions. The methods and processes can be extended to other systems, such as those with multiple antennas in an individual sector and those where some subcarriers bear common network/system information.

30 Claims, 13 Drawing Sheets



Related U.S. Application Data

No. 15/688,441, filed on Aug. 28, 2017, now Pat. No. 10,326,631, which is a continuation of application No. 14/746,676, filed on Jun. 22, 2015, now Pat. No. 9,749,168, which is a continuation of application No. 14/595,132, filed on Jan. 12, 2015, now Pat. No. 9,065,614, which is a continuation of application No. 13/874,278, filed on Apr. 30, 2013, now Pat. No. 8,934,473, which is a continuation of application No. 13/212,116, filed on Aug. 17, 2011, now Pat. No. 8,432,891, which is a continuation of application No. 10/583,530, filed as application No. PCT/US2005/001939 on Jan. 20, 2005, now Pat. No. 8,009,660.

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2005/0111397	A1	5/2005	Attar et al.
2006/0114815	A1	6/2006	Hasegawa
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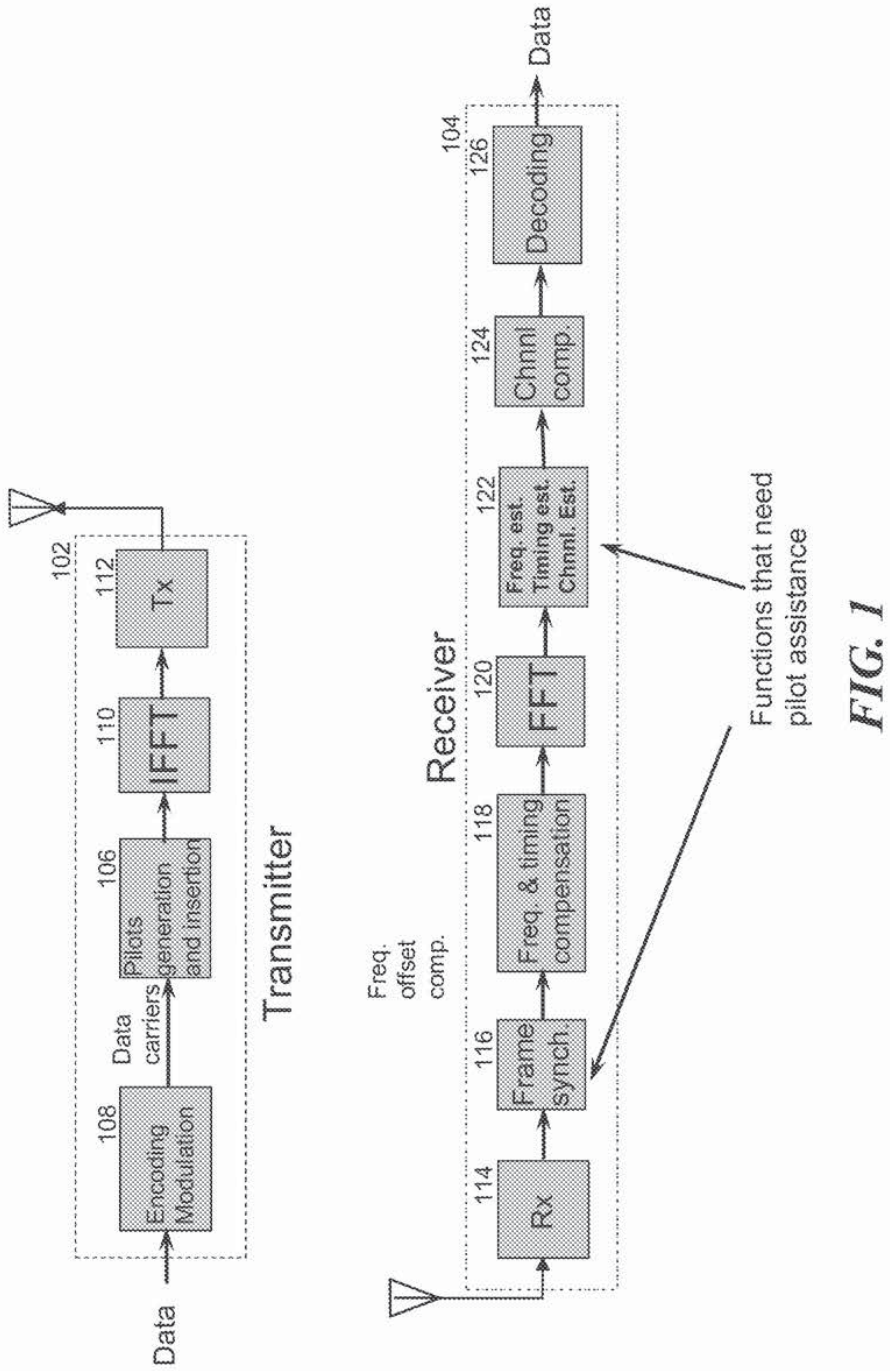

Data
Transmitter
102
Tx
112
IFFT
110
Pilots generation and insertion
106
Data carriers
Encoding Modulation
108
Receiver
104
Decoding
126
Data
Chnnl comp
124
Freq. est. Timing est. Chnnl. Est.
122
FFT
120
Freq. & timing compensation
118
Frame synch
116
Rx
114
Freq. offset comp.
Functions that need pilot assistance

FIG. 1

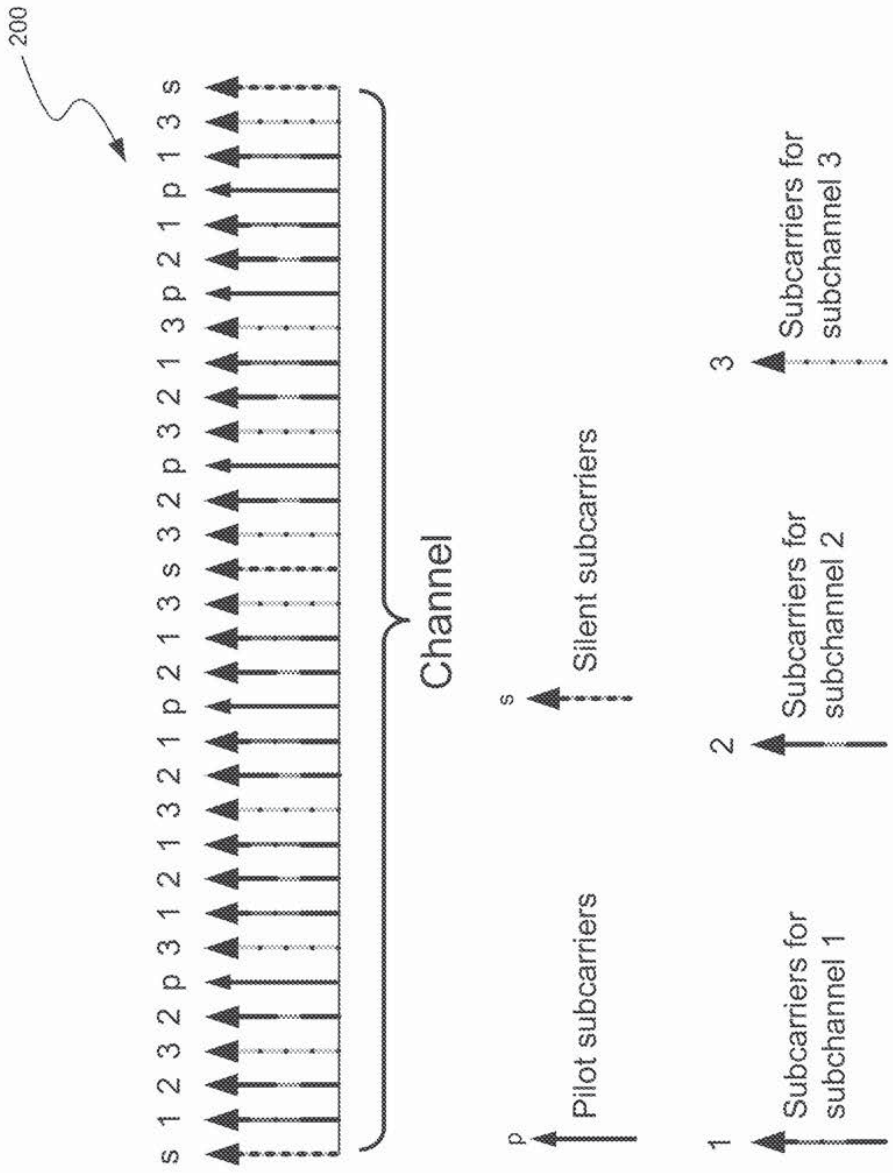

200
s 1 2 3 2 p 3 1 2 1 3 2 1 p 2 1 3 s 3 2 p 3 2 1 3 p 2 1 p 1 3 s
Channel
p
Pilot subcarriers
s
Silent subcarriers
1
Subcarriers for subchannel 1
2
Subcarriers for subchannel 2
3
Subcarriers for subchannel 3

FIG. 2

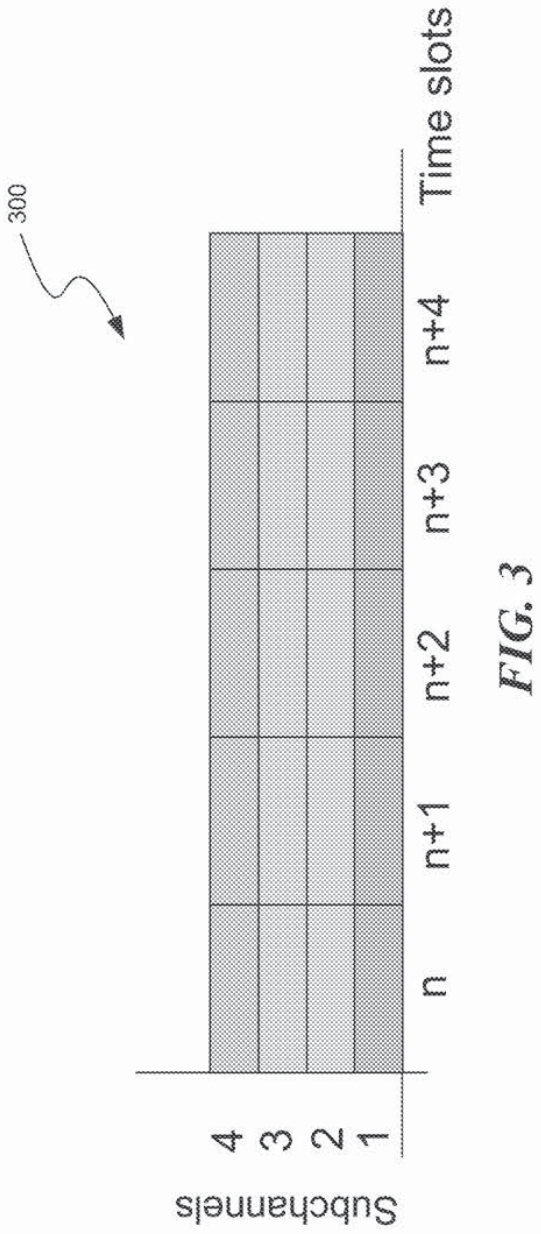


FIG. 3

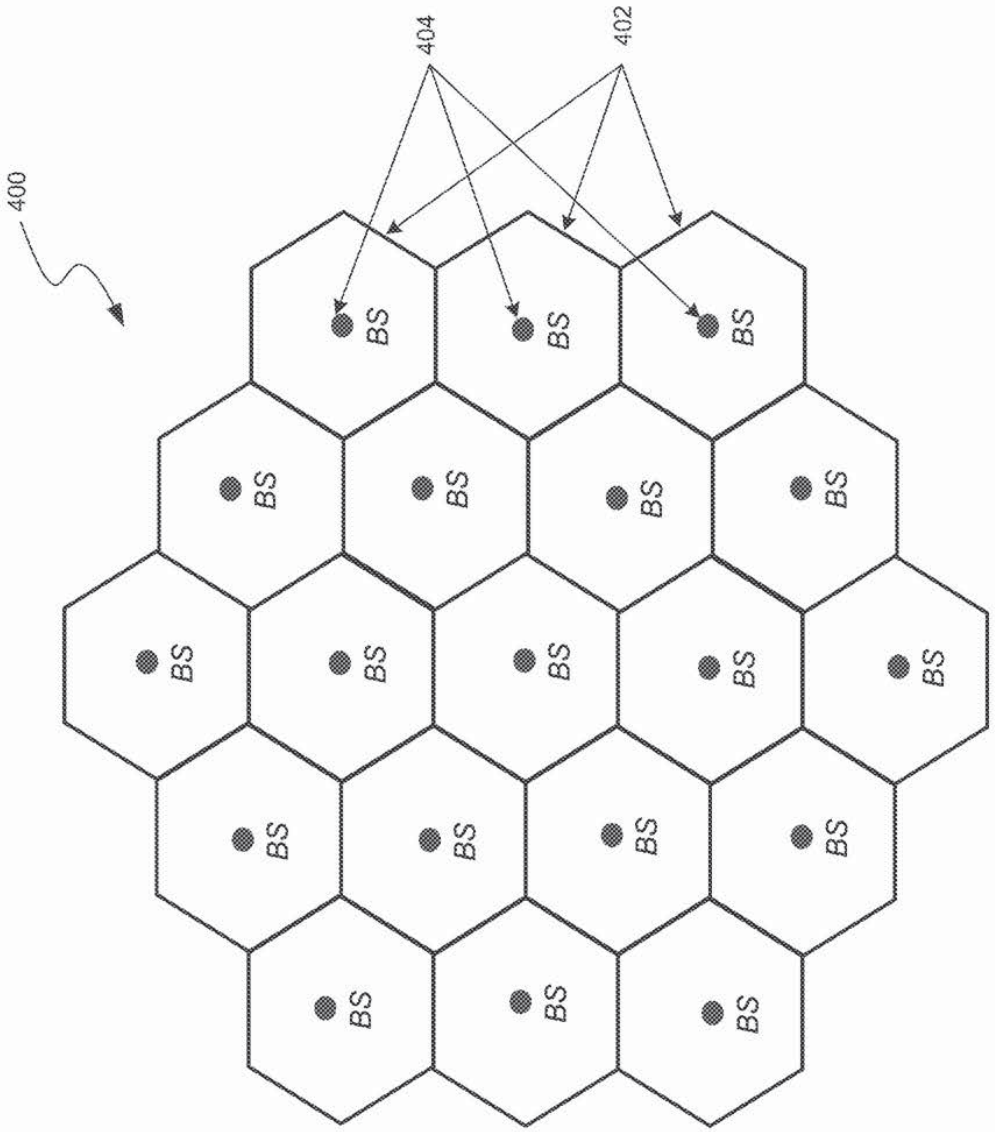


FIG. 4

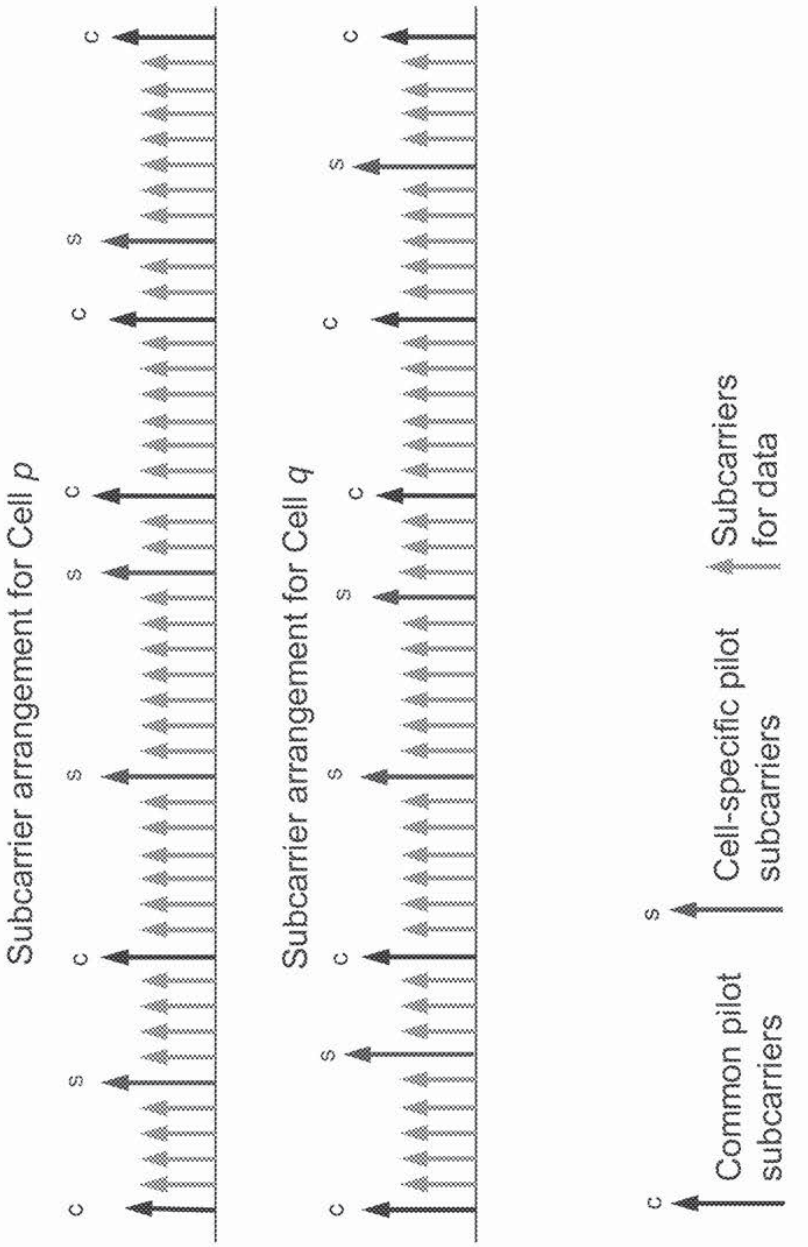

Subcarrier arrangement for Cell p
Subcarrier arrangement for Cell q
Common pilot subcarriers
Cell-specific pilot subcarriers
Subcarriers for data

FIG. 5

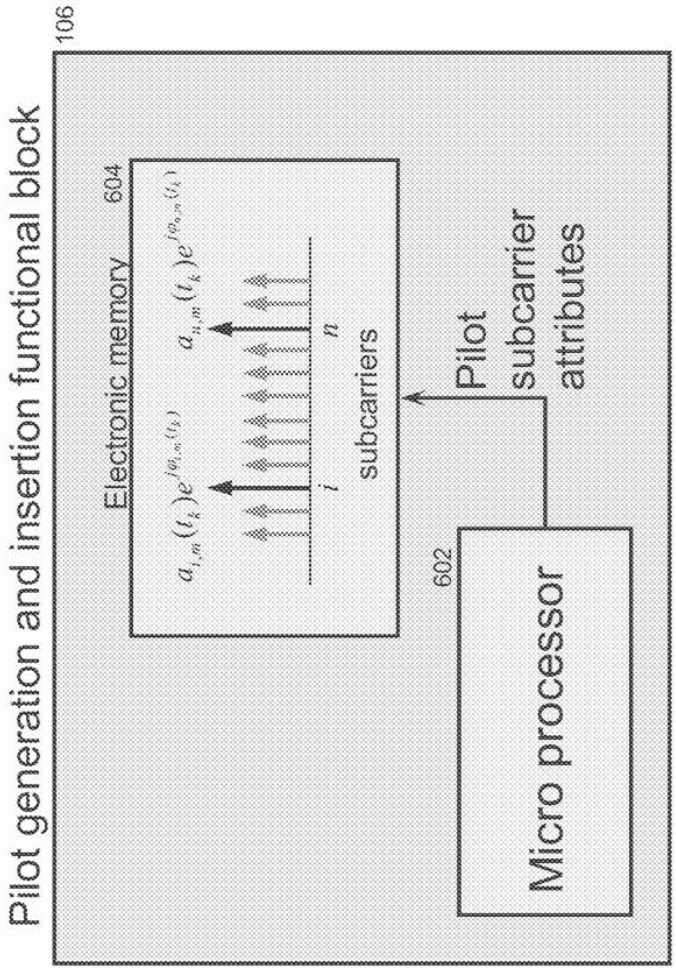

106
Pilot generation and insertion functional block
Electronic memory
604
$a_{1,m}(t_k)e^{j\theta_{1,m}(t_k)}$
$a_{n,m}(t_k)e^{j\theta_{n,m}(t_k)}$
1
n
subcarriers
Pilot subcarrier attributes
602
Micro processor

FIG. 6

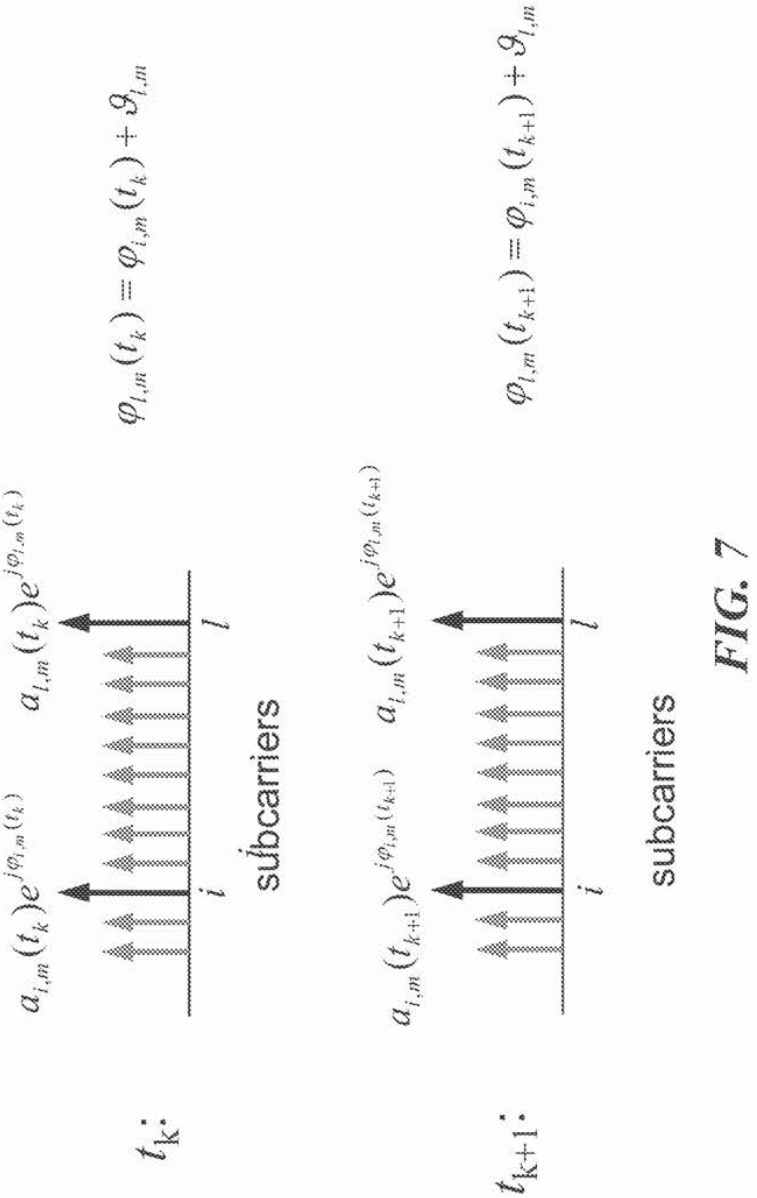

$\varphi_{l,m}(t_k) = \varphi_{i,m}(t_k) + \vartheta_{l,m}$
$a_{l,m}(t_k)e^{j\varphi_{l,m}(t_k)}$
$a_{l,m}(t_k)e^{j\varphi_{l,m}(t_k)}$
t_k:
i
l
subcarriers
$\varphi_{l,m}(t_{k+1}) = \varphi_{i,m}(t_{k+1}) + \vartheta_{l,m}$
$a_{i,m}(t_{k+1})e^{j\varphi_{i,m}(t_{k+1})}$
$a_{l,m}(t_{k+1})e^{j\varphi_{l,m}(t_{k+1})}$
t_{k+1}:
i
l
subcarriers

FIG. 7

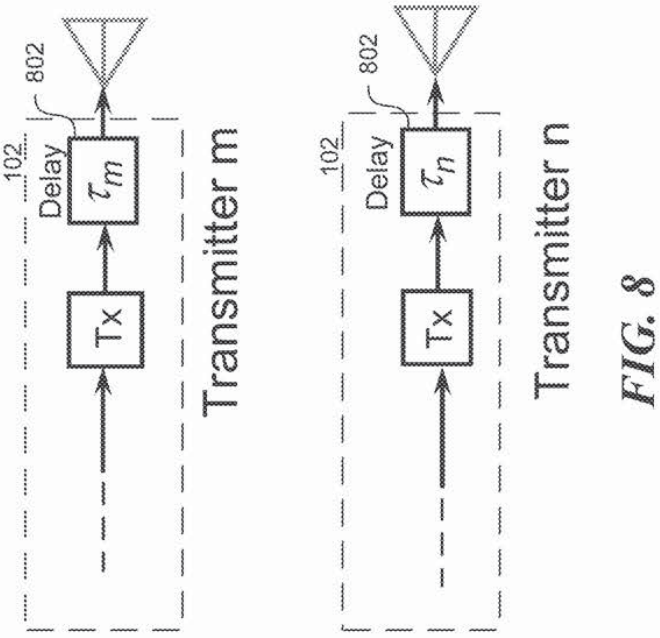

802
102
Delay
τ_m
Tx
Transmitter m
802
102
Delay
τ_n
Tx
Transmitter n

FIG. 8

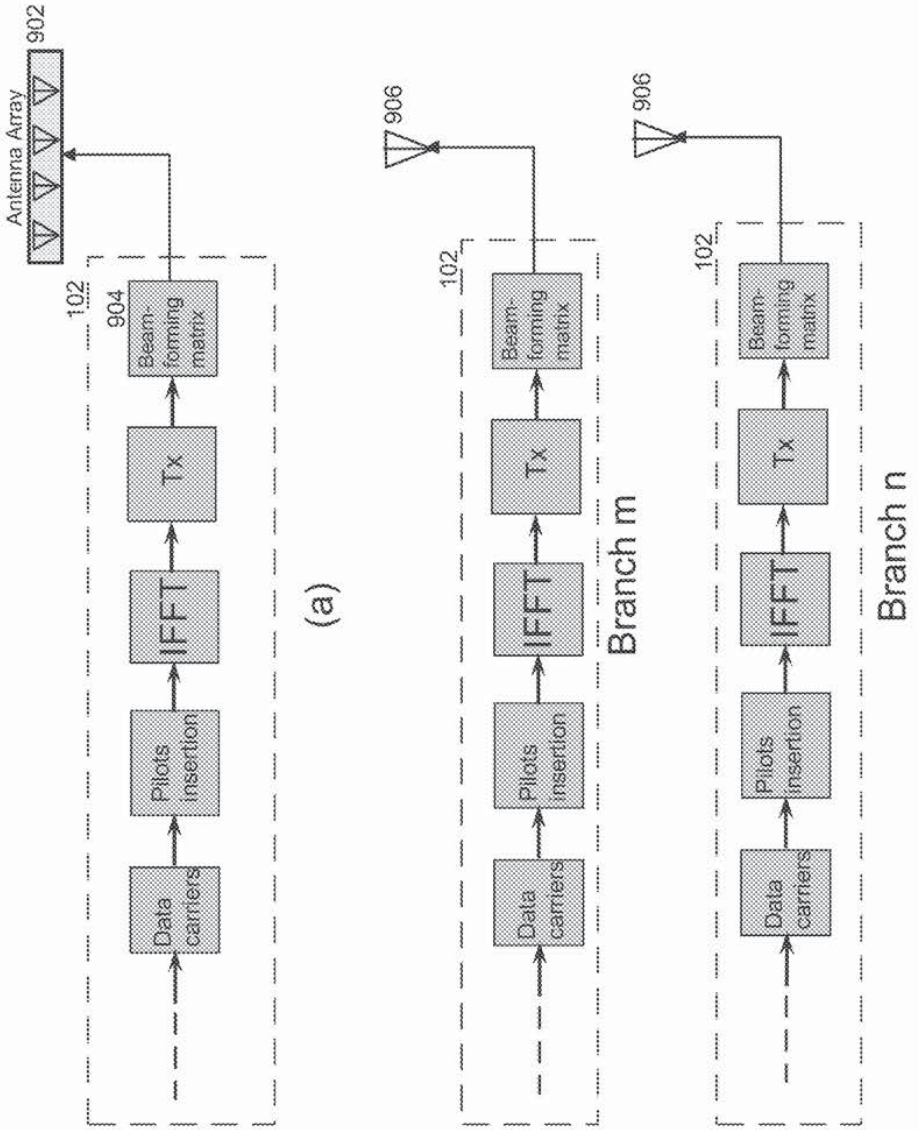

Antenna Array
902
102
904
Beam-forming matrix
Tx
IFFT
Pilots insertion
Data carriers
(a)
906
102
Beam-forming matrix
Tx
IFFT
Pilots insertion
Data carriers
Branch m
906
102
Beam-forming matrix
Tx
IFFT
Pilots insertion
Data carriers
Branch n
(b)

FIG. 9

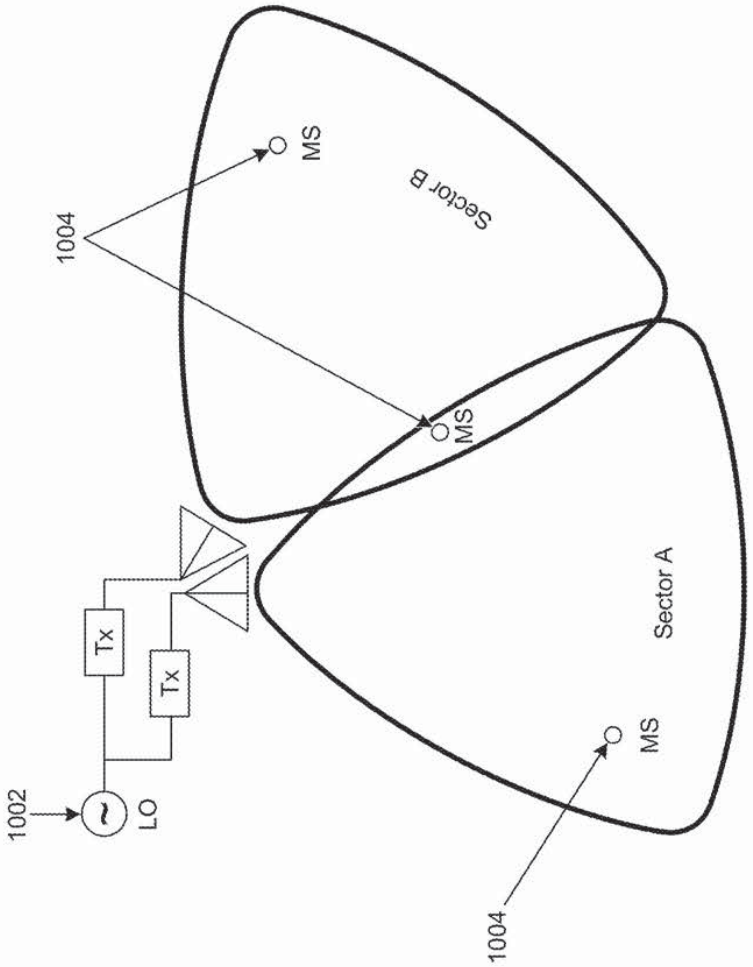


FIG. 10

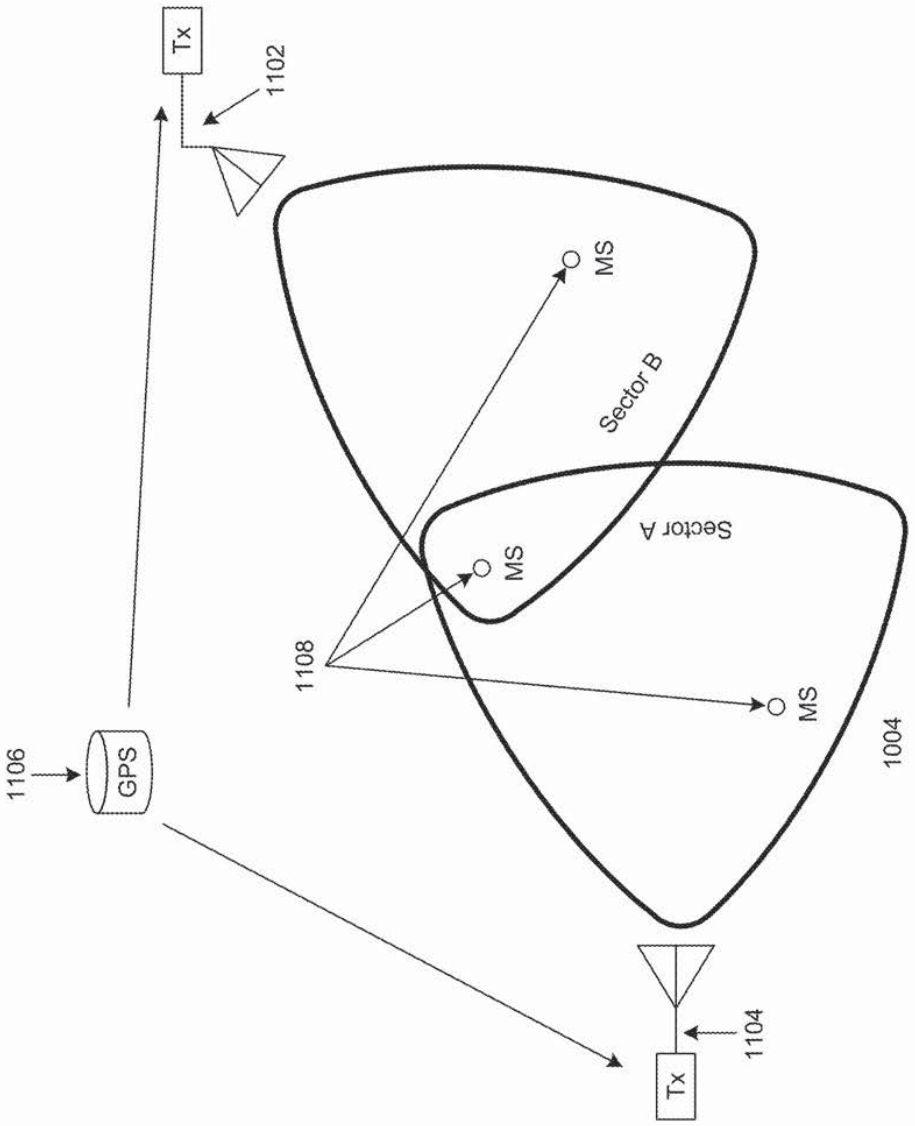


FIG. 11

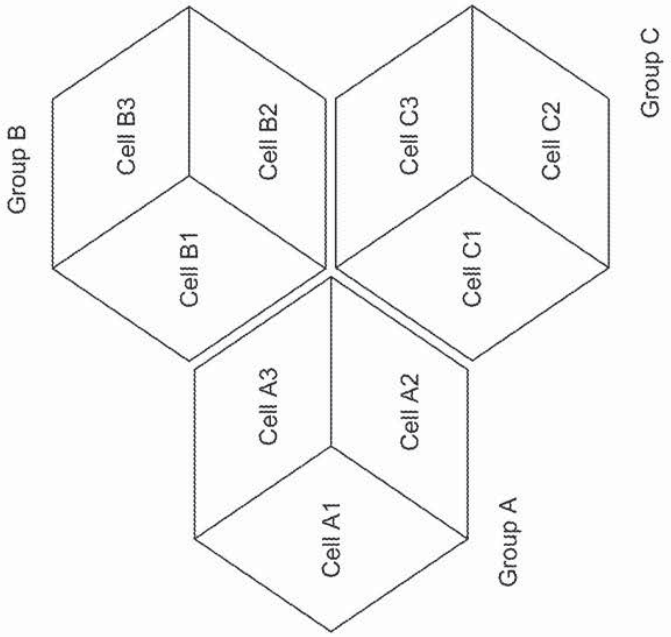

Group B
Cell B3
Cell B2
Cell B1
Group C
Cell C3
Cell C2
Cell C1
Cell A3
Cell A2
Cell A1
Group A

FIG. 12

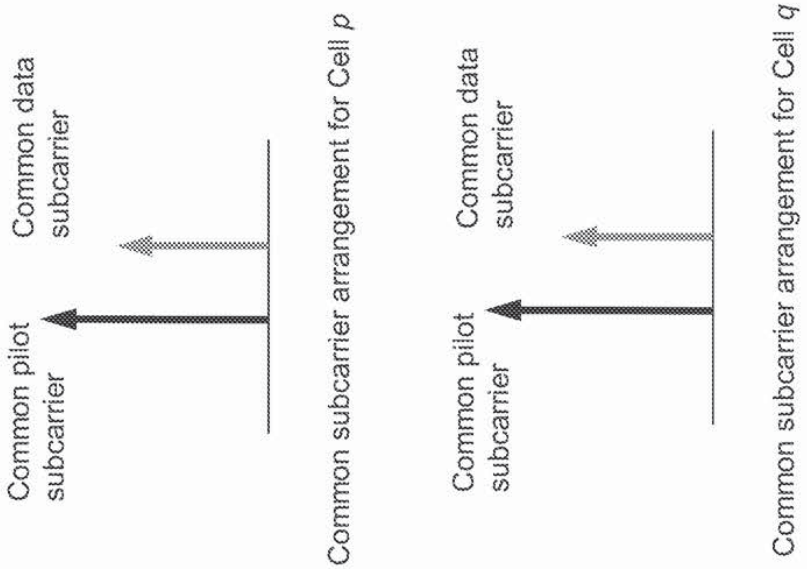

Common pilot subcarrier
Common data subcarrier
Common subcarrier arrangement for Cell p
Common pilot subcarrier
Common data subcarrier
Common subcarrier arrangement for Cell q

FIG. 13

METHOD AND APPARATUS USING CELL-SPECIFIC AND COMMON PILOT SUBCARRIERS IN MULTI-CARRIER, MULTI CELL WIRELESS COMMUNICATION NETWORKS

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of U.S. patent application Ser. No. 16/440,754, filed Jun. 13, 2019, which is a continuation of U.S. patent application Ser. No. 15/688,441, filed Aug. 28, 2017, which issued as U.S. Pat. No. 10,326,631 on Jun. 18, 2019, which is a continuation of U.S. patent application Ser. No. 14/746,676, filed Jun. 22, 2015, which issued as U.S. Pat. No. 9,749,168 on Aug. 29, 2017, which is a continuation of U.S. patent application Ser. No. 14/595,132, filed Jan. 12, 2015, which issued as U.S. Pat. No. 9,065,614 on Jun. 23, 2015, which is a continuation of U.S. patent application Ser. No. 13/874,278, filed Apr. 30, 2013, which issued as U.S. Pat. No. 8,934,473 on Jan. 13, 2015, which is a continuation of U.S. patent application Ser. No. 13/212,116, filed Aug. 17, 2011, which issued as U.S. Pat. No. 8,432,891 on Apr. 30, 2013, which is a continuation of U.S. patent application Ser. No. 10/583,530, filed May 30, 2007, which issued as U.S. Pat. No. 8,009,660 on Aug. 30, 2011, which is a U.S. National Stage of PCT Application No. PCT/US05/01939, filed Jan. 20, 2005, which claims the benefit of and priority to U.S. Provisional Patent Application No. 60/540,032, filed on Jan. 29, 2004, the entire contents of all of which are hereby incorporated by reference herein.

BACKGROUND

In multi-carrier wireless communications, many important system functions such as frequency synchronization and channel estimation, depicted in FIG. **1**, are facilitated by using the network information provided by a portion of total subcarriers such as pilot subcarriers. The fidelity level of the received subcarriers dictates how well these functions can be achieved, which in turn affect the efficiency and capacity of the entire network.

In a wireless network, there are a number of base stations, each of which provides coverage to designated areas, normally called a cell. If a cell is divided into sectors, from a system engineering point of view each sector can be considered a cell. In this context, the terms "cell" and "sector" are interchangeable. The network information can be categorized into two types: the cell-specific information that is unique to a particular cell, and the common information that is common to the entire network or to a portion of the entire networks such as a group of cells.

In a multi-cell environment, for example, the base station transmitter of each cell transmits its own pilot subcarriers, in addition to data carriers, to be used by the receivers within the cell. In such an environment, carrying out the pilot-dependent functions becomes a challenging task in that, in addition to the degradation due to multipath propagation channels, signals originated from the base stations at different cells interfere with each other.

One approach to deal with the interference problem has been to have each cell transmit a particular pattern of pilot subcarriers based on a certain type of cell-dependent random process. This approach, to a certain degree, has mitigated the impact of the mutual interference between the pilot subcarriers from adjacent cells; however, it has not provided for a careful and systematic consideration of the unique requirements of the pilot subcarriers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a basic multi-carrier wireless communication system consisting of a transmitter and a receiver.

FIG. **2** shows basic structure of a multi-carrier signal in the frequency domain, which is made up of subcarriers.

FIG. **3** shows a radio resource divided into small units in both the frequency and time domains: subchannels and time slots.

FIG. **4** depicts a cellular wireless network comprised of multiple cells, in each of which coverage is provided by a base station (BS).

FIG. **5** shows pilot subcarriers divided into two groups: cell-specific pilot subcarriers and common pilot subcarriers.

FIG. **6** is an embodiment of pilot-generation-and-insertion functional block shown in FIG. **1**, which employs a microprocessor to generate pilot subcarriers and insert them into a frequency sequence contained in the electronic memory.

FIG. **7** shows that common pilot subcarriers are generated by a microprocessor of FIG. **6** to realize phase diversity.

FIG. **8** is an embodiment of delay diversity, which effectively creates phase diversity by adding a random delay time duration, either in baseband or RF, to the time-domain signals.

FIG. **9** shows two examples for extension to multiple antenna applications.

FIG. **10** is an embodiment of synchronization in frequency and time domains of two collocated base stations sharing a common frequency oscillator.

FIG. **11** is an embodiment of synchronization in frequency and time domains with base stations at different locations sharing a common frequency reference signal generated from the GPS signals.

FIG. **12** is an embodiment depicting a wireless network consisting of three groups of cells (or sectors) and base stations in each group that share their own set of common pilot subcarriers.

FIG. **13** shows all base stations within a network transmit, along with a common pilot subcarrier, a data subcarrier carrying data information common to all cells in the network.

DETAILED DESCRIPTION

In the following description the invention is explained with respect to some of its various embodiments, providing specific details for a thorough understanding and enablement. However, one skilled in the art will understand that the invention may be practiced without such details. In other instances, well-known structures and functions have not been shown or described in detail to avoid obscuring the depiction of the embodiments.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the

following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

FIG. **1** depicts a basic multi-carrier wireless communication system consisting of a transmitter **102** and a receiver **104**. A functional block **106** at the transmitter, called Pilot generation and insertion, generates pilot subcarriers and inserts them into predetermined frequency locations. These pilot subcarriers are used by the receiver to carry out certain functions. In aspects of this invention, pilot subcarriers are divided into two different groups according to their functionalities, and hence their distinct requirements. The transmission format of each group of pilot subcarriers will be designed so that it optimizes the performance of the system functions such as frequency synchronization and channel estimation.

The first group is called "cell-specific pilot subcarriers," and will be used by the receiver **104** to extract information unique to each individual cell. For example, these cell-specific pilot subcarriers can be used in channel estimation where it is necessary for a particular receiver to be able to differentiate the pilot subcarriers that are intended for its use from those of other cells. For these pilot subcarriers, counter-interference methods are necessary.

The second group is termed "common pilot sub-carriers," and are designed to possess a set of characteristics common to all base stations of the system. Thus, every receiver **104** within the system is able to exploit these common pilot subcarriers to perform necessary functions without interference problem. For instance, these common pilot subcarriers can be used in the frequency synchronization process, where it is not necessary to discriminate pilot subcarriers of different cells, but it is desirable for the receiver to combine coherently the energy of common pilot subcarriers with the same carrier index from different cells, so as to achieve relatively accurate frequency estimation.

Aspects of this invention provide methods to define the transmission formats of the cell-specific and common pilot subcarriers that enable a receiver to perform different system functions. In particular, a set of design criteria are provided for pilot subcarriers. Other features of this invention further provide apparatus or means to implement the above design processes and methods. In particular, signal reception can be improved by manipulating phase values of the pilot subcarriers and by using power control.

The methods and processes can also be extended to other cases, such as where multiple antennas are used within an individual sector and where some subcarriers are used to carry common network/system information. Base stations can be synchronized in frequency and time by sharing a common frequency oscillator or a common frequency reference signal, such as the one generated from the signals provided by the Global Positioning System (GPS).

Multi-Carrier Communication System

In a multi-carrier communication system such as multi-carrier code division multiple access (MC-CDMA) and orthogonal frequency division multiple access (OFDMA), information data are multiplexed on subcarriers that are mutually orthogonal in the frequency domain. In effect, a frequency selective channel is broken into a number of parallel but small segments in frequency that can be treated as flat fading channels and hence can be easily dealt with using simple one-tap equalizers. The modulation/demodulation can be performed using the fast Fourier transform (FFT).

In a multi-carrier communication system the physical media resource (e.g., radio or cable) can be divided in both the frequency and the time domains. This canonical division provides a high flexibility and fine granularity for resource sharing. The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers, and within a particular spectral band or channel there are a fixed number of subcarriers. There are three types of subcarriers:

1. Data subcarriers, which carry information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are used for assisting system functions such as estimation of system parameters; and
3. Silent subcarriers, which have no energy and are used for guard bands and DC carriers.

The data subcarriers can be arranged into groups called subchannels to support multiple access and scalability. The subcarriers forming one subchannel are not necessarily adjacent to each other. This concept is illustrated in FIG. **2**, showing a basic structure of a multi-carrier signal **200** in the frequency domain, which is made up of subcarriers. Data subcarriers can be grouped into subchannels in a particular way. The pilot subcarriers are also distributed over the entire channel in a particular way.

The basic structure of a multi-carrier signal in the time domain is made up of time slots to support multiple-access. The resource division in both the frequency and time domains is depicted in FIG. **3** which shows a radio resource divided into small units in both the frequency and time domains: subchannels and time slots, **300**. The basic structure of a multi-carrier signal in the time domain is made up of time slots.

As depicted in FIG. **1**, in a multi-carrier communication system, a generic transmitter may consist of the following functional blocks:

1. Encoding and modulation **108**
2. Pilot generation and insertion **106**
3. Inverse fast Fourier transform (IFFT) **110**
4. Transmission **112**

And a generic receiver may consist of the following functional blocks:

1. Reception **114**
2. Frame synchronization **116**
3. Frequency and timing compensation **118**
4. Fast Fourier transform (FFT) **120**
5. Frequency, timing, and channel estimation **122**
6. Channel compensation **124**
7. Decoding **126**

Cellular Wireless Networks

In a cellular wireless network, the geographical region to be serviced by the network is normally divided into smaller areas called cells. In each cell the coverage is provided by a base station. Thus, this type of structure is normally referred to as the cellular structure depicted in FIG. **4**, which illustrates a cellular wireless network **400** comprised of multiple cells **402**, in each of which coverage is provided by a base station (BS) **404**. Mobile stations are distributed within each coverage area.

A base station **404** is connected to the backbone of the network via a dedicated link and also provides radio links to mobile stations within its coverage. A base station **404** also serves as a focal point to distribute information to and collect information from its mobile stations by radio signals. The mobile stations within each coverage area are used as the interface between the users and the network.

In an M-cell wireless network arrangement, with one-way or two-way communication and time division or frequency division duplexing, the transmitters at all the cells are synchronized via a particular means and are transmitting

simultaneously. In a specific cell **402** of this arrangement, the pth cell, a receiver receives a signal at a specific subcarrier, the ith subcarrier, at the time t_k, which can be described as:

$$s_i(t_k) = a_{i,p}(t_k)e^{j\varphi_{i,p}(t_k)} + \sum_{\substack{m=1 \\ m\neq p}}^{M} a_{i,m}(t_k)e^{j\varphi_{i,m}(t_k)} \quad (1)$$

where $a_{i,m}(t_k)$ and $\varphi_{i,m}(t_k)$ denote the signal amplitude and phase, respectively, associated with the i^{th} subcarrier from the base station of the m_{th} cell.

Cell-Specific Pilot Subcarriers

If the ith subcarrier is used as a pilot subcarrier at the pth cell for the cell-specific purposes, the cell-specific information carried by $a_{i,p}(t_k)$ and $\varphi_{i,p}(t_k)$ will be of interest to the receiver at the pth cell and other signals described by the second term on the right hand side of equation (1) will be interference, which is an incoherent sum of signals from other cells. In this case, a sufficient level of the carrier-to-interference ratio (CIR) is required to obtain the estimates of $a_{i,p}(t_k)$ and $\varphi_{i,p}(t_k)$ with desirable accuracy.

There are many ways to boost the CIR. For examples, the amplitude of a pilot subcarrier can be set larger than that of a data subcarrier; power control can be applied to the pilot subcarriers; and cells adjacent to the pth cell may avoid using the ith subcarrier as pilot subcarrier. All these can be achieved with coordination between the cells based on certain processes, described below.

Common Pilot Subcarriers

The common pilot subcarriers for different cells are normally aligned in the frequency index at the time of transmission, as depicted in FIG. **5**, which shows pilot subcarriers divided into two groups: cell-specific pilot subcarriers and common pilot subcarriers. The cell-specific pilot subcarriers for different cells are not necessarily aligned in frequency. They can be used by the receiver to extract cell-specific information. The common pilot subcarriers for different cells may be aligned in frequency, and possess a set of attributes common to all base stations within the network. Thus, every receiver within the system is able to exploit these common pilot subcarriers without interference problem. The power of the pilot subcarriers can be varied through a particular power control scheme and based on a specific application.

If the ith subcarrier is used as a pilot subcarrier at the pth cell for the common purposes, it is not necessary to consider the second term on the right hand side of equation (1) to be interference. Instead, this term can be turned into a coherent component of the desirable signal by designing the common pilot carriers to meet the criteria specified in the aspects of this invention, provided that base stations at all cells are synchronized in frequency and time. In such a case the cell in which the receiver is located becomes irrelevant and, consequently, the received signal can be rewritten as:

$$s_i(t_k) = \sum_{m=1}^{M} a_{i,m}(t_k)e^{j\varphi_{i,m}(t_k)} \quad (2)$$

The common pilot subcarriers can be used for a number of functionalities, such as frequency offset estimation and timing estimation.

To estimate the frequency, normally signals at different times are utilized. In an example with two common pilot subcarriers of the same frequency index, the received signal at time t_{k+1}, with respect to the received signal at time t_k, is given by

$$s_i(t_{k+1}) = e^{j2\pi f_i \Delta t}\sum_{m=1}^{M} a_{i,m}(t_{k+1})e^{j\varphi_{i,m}(t_{k+1})} \quad (3)$$

where $\Delta t = t_{k+1} - t_k$. If Δt is much less than the coherence period of the channel and

$$\alpha_{i,m}(t_k) = c_i\alpha_{i,m}(t_{k+1}) \quad (4)$$

and

$$\phi_{i,m}(t_k) = \phi_{i,m}(t_{k+1}) + \beta_i \quad (5)$$

then the frequency can be determined by

$$2\pi f_i \Delta t = arg\{s_i(k)s_i(k+1)\} - \beta_i \quad (6)$$

where $c_i > 0$ and $-\pi \le \beta_i \le \pi$ or are predetermined constants for all values of m. And from all the frequency estimates $\{f_i\}$, a frequency offset can be derived based on a certain criterion.

For timing estimation, normally multiple common pilot carriers are required. In an example of two common pilot subcarriers, the received signal at f_n, is given by

$$s_n(t_k) = e^{j2\pi\Delta f T_s(t_k)}\sum_{m=1}^{M} a_{n,m}(t_k)e^{j\varphi_{n,m}(t_k)} \quad (7)$$

where $\Delta f = f_n - f_i$ and T_s denotes the sampling period. If Δf is much less than the coherence bandwidth of the channel and

$$\alpha_{i,m}(t_k) = c(t_k)\alpha_{n,m}(t_k) \quad (8)$$

and

$$\phi_{i,m}(t_k) = \phi_{n,m}(t_k) + \gamma(t_k) \quad (9)$$

then T_s can be determined by

$$2\pi\Delta f T_s(t_k) = arg\{s_i^*(t_k)s_n(t_k)\} - \gamma(t_k) \quad (10)$$

where $c(t_k) > 0$ and $-\pi \le \gamma(t_k) \le \pi$ are predetermined constants for all values of m.

FIG. **6** is an embodiment of pilot-generation-and-insertion functional block **106** shown in FIG. **1**, which employs a microprocessor **602** to generate pilot subcarriers and insert them into a frequency sequence contained in electronic memory **604**. In one embodiment of the invention illustrated in FIG. **6**, a microprocessor **602** embedded in the pilot-generation-and-insertion functional block **106** computes the attributes of the pilot subcarriers such as their frequency indices and complex values specified by their requirements, and insert them into the frequency sequence contained in the electronic memory **604**, such as a RAM, ready for the application of IFFT.

Diversity for Common Pilot Subcarriers

Considering equation (2), which is the sum of a number of complex signals, it is possible for these signals to be destructively superimposed on each other and cause the amplitude of the receiver signal at this particular subcarrier to be so small that the signal itself becomes unreliable. Phase diversity can help this adverse effect. In the example of

frequency estimation, a random phase $\vartheta_{l,m}$ can be added to another pilot subcarrier, say the Ith subcarrier, which results in

$$\phi_{l,m}(t_k)=\phi_{i,m}(t_k)+\vartheta_{l,m} \quad (11)$$

and

$$\phi_{l,m}(t_{k+1})=\phi_{i,m}(t_{k+1})+\vartheta_{l,m} \quad (12)$$

where **248** $_{l,m}$ should be set differently for each cell, and provided that the following condition is met,

$$\phi_{l,m}(t_k)=\phi_{l,m}(t_{k+1})+\beta_i, \text{ for all values of } m \quad (13)$$

With the phase diversity, it is expected that the probability of both $|s_i(t_k)|$ and $|s_i(t_k)|$ diminishing at the same time is relatively small. The embodiment of phase diversity is depicted in FIG. **7**, which shows common pilot subcarriers generated by a microprocessor of FIG. **6** to realize phase diversity. It should be noted that time delay will achieve the equivalent diversity effect.

Another embodiment is illustrated in FIG. **8**, which effectively creates phase diversity by adding a random delay time duration **802**, either in baseband or RF, to the time-domain signals.

Power Control for Pilot Subcarriers

In one embodiment of the invention, power control can be applied to the pilot subcarriers. The power of the pilot subcarriers can be adjusted individually or as a subgroup to

1. meet the needs of their functionalities;
2. adapt to the operation environments (e.g., propagation channels); and
3. reduce interference between cells or groups of cells.

In another embodiment power control is implemented differently for cell-specific pilot subcarriers and common pilot subcarriers. For example, stronger power is applied to common pilot subcarriers than to the cell-specific subcarriers.

Application to Multiple Antennas

The methods and processes provided by this invention can also be implemented in applications where multiple antennas are used within an individual sector, provided that the criteria specified either by equations (4) and (5) for frequency estimation or by equations (8) and (9) for timing estimation are satisfied.

FIG. **9** shows two examples for extension to multiple antenna applications. In case (a) where there is only one transmission branch that is connected to an array of antennas **902** through a transformer **904** (e.g., a beam-forming matrix), the implementation is exactly the same as in the case of single antenna. In case (b) of multiple transmission branches connected to different antennas **906** (e.g., in a transmission diversity scheme or a multiple-input multiple-output scheme), the cell-specific pilot subcarriers for transmission branches are usually defined by a multiple-antenna scheme whereas the common pilot subcarriers for each transmission branch are generated to meet the requirements of (4) and (5) for frequency estimation or (8) and (9) for timing estimation.

Joint-Use of Cell-Specific and Common Pilot Subcarriers

In one embodiment the cell-specific and common pilot subcarriers can be used jointly in the same process based on certain information theoretic criteria, such as the optimization of the signal-to-noise ratio. For example, in the estimation of a system parameter (e.g. frequency), some or all cell-specific subcarriers, if they satisfy a certain criterion, such as to exceed a CIR threshold, may be selected to be used together with the common pilot subcarriers to improve estimation accuracy. Furthermore, the common pilot subcarriers can be used along with the cell-specific subcarriers to determine the cell-specific information in some scenarios, one of which is the operation at the edge of the network.

Base Transmitters Synchronization

Base stations at all cells are required to be synchronized in frequency and time. In one embodiment of the invention the collocated base station transmitters are locked to a single frequency oscillator, as in the case where a cell is divided into sectors and the base stations of these sectors are physically placed at the same location.

FIG. **10** is an embodiment of synchronization in frequency and time domains of two collocated base stations sharing a common frequency oscillator **1002**. Mobile stations **1004** covered by these two base stations do not experience interference when receiving the common pilot subcarriers. The base station transmitters that are located at different areas are locked to a common reference frequency source, such as the GPS signal. FIG. **11** depicts an embodiment of synchronization in frequency and time domains with base stations **1102** and **1104** at different locations sharing a common frequency reference signal generated from the GPS **1106** signals. Mobile stations **1108** covered by these two base stations **1102** and **1104** do not experience interference when receiving the common pilot subcarriers.

In some applications, the entire wireless network may consist of multiple groups of cells (or sectors) and each group may have its own set of common pilot subcarriers. In such scenarios, only those base stations within their group are required to synchronize to a common reference. While the common pilot subcarriers within each group are designed to meet the criteria defined by equations (4) and (5) or by (8) and (9) for the use by its base stations, a particular counter-interference process (e.g., randomization in frequency or power control) will be applied to different sets of common pilot subcarriers. This will cause the signals from the cells within the same group to add coherently while the signals from the cells in other groups are treated as randomized interference.

One embodiment of such implementation is illustrated in FIG. **12**, where a wireless network consists of three groups (A, B, and C) of cells (or sectors). The base stations within their own group share the same set of common pilot subcarriers. In this scenario, only those base stations within their group are required to synchronize to a common reference. While the common pilot subcarriers within each group are designed to meet the criteria defined in this invention, a particular counter-interference process (e.g., randomization in frequency) will be applied to different sets of common pilot subcarriers. For example, the base stations at Cells A1, A2, and A3 in Group A synchronize to their own common reference source and transmit the same set of common pilot subcarriers; and the base stations at Cells B1, B2, and B3 in Group B synchronize to their own reference source and transmit another set of common pilot subcarriers that are located at different places in the frequency domain.

Extension to Transmission of Data Information

All design processes, criteria, and methods described in the embodiments of this invention can be extended to applications where common network information is required to be distributed to all receivers within the network. In one example, all the base stations within the network transmit, along with some common pilot subcarriers, an identical set of data subcarriers in which the data information common to all the cells in the network is imbedded.

FIG. **13** shows all base stations within a network transmit, along with a common pilot subcarrier, a data subcarrier carrying data information common to all cells in the net-

work. A receiver within the network can determine the composite channel coefficient based on the common pilot subcarrier and apply it to the data subcarrier to compensate for the channel effect, thereby recovering the data information.

The above detailed descriptions of embodiments of the invention are not intended to be exhaustive or to limit the invention to the precise form disclosed above. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. For example, while steps are presented in a given order, alternative embodiments may perform routines having steps in a different order. The teachings of the invention provided herein can be applied to other systems, not necessarily the system described herein. These and other changes can be made to the invention in light of the detailed description.

The elements and acts of the various embodiments described above can be combined to provide further embodiments.

These and other All of the above U.S. patents and applications and other references are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions and concepts of the various references described above to provide yet further embodiments of the invention.

Changes can be made to the invention in light of the above detailed description. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above detailed description explicitly defines such terms. Accordingly, the actual scope of the invention encompasses the disclosed embodiments and all equivalent ways of practicing or implementing the invention under the claims.

While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. For example, while only one aspect of the invention is recited as embodied in a computer-readable medium, other aspects may likewise be embodied in a computer-readable medium. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.

What is claimed is:

1. An orthogonal frequency division multiple access (OFDMA)-compatible base station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible base station comprising:

a plurality of antennas; and

a transmitter operably coupled to the plurality of antennas;

the transmitter configured to:

insert first pilots of a first type onto a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and

insert data and second pilots of a second type onto a second plurality of subcarriers;

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

the plurality of antennas configured to transmit the first plurality of subcarriers and the second plurality of subcarriers in at least one of the time slots;

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.

2. The OFDMA-compatible base station of claim **1** wherein all subcarriers of the first plurality of subcarriers are different than all subcarriers of the second plurality of subcarriers.

3. The OFDMA-compatible base station of claim **1** wherein the second plurality of subcarriers includes an n^{th} subcarrier and an n+18 subcarrier spaced apart from the n^{th} subcarrier by 17 subcarriers and the first plurality of subcarriers includes an m^{th} subcarrier and an m+20 subcarrier spaced apart from the m^{th} subcarrier by 19 subcarriers.

4. The OFDMA-compatible base station of claim **1** wherein each cell-specific pilot of the cell-specific pilots is unique to a respective cell.

5. The OFDMA-compatible base station of claim **1** wherein the first plurality of subcarriers are not aligned in frequency with subcarriers of at least another cell onto which respective cell-specific pilots are inserted.

6. The OFDMA-compatible base station of claim **1** wherein the second plurality of subcarriers are beam-formed.

7. The OFDMA-compatible base station of claim **1** wherein the cell-specific pilots are used to convey cell-specific information.

8. A method performed by an orthogonal frequency division multiple access (OFDMA)-compatible base station that uses subcarriers in a frequency domain and time slots in a time domain, the method comprising:

inserting, by the OFDMA-compatible base station, first pilots of a first type onto a first plurality of subcarriers, wherein the first pilots are cell-specific pilots;

inserting, by the OFDMA-compatible base station, data and second pilots of a second type onto a second plurality of subcarriers;

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

transmitting, by the OFDMA-compatible base station, the first plurality of subcarriers and the second plurality of subcarriers in at least one of the time slots using a plurality of antennas;

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.

9. The method of claim **8** wherein all subcarriers of the first plurality of subcarriers are different than all subcarriers of the second plurality of subcarriers.

10. The method of claim **8** wherein the second plurality of subcarriers includes an n^{th} subcarrier and an n+18 subcarrier spaced apart from the n^{th} subcarrier by 17 subcarriers and the first plurality of subcarriers includes an m^{th} subcarrier and an m+20 subcarrier spaced apart from the m^{th} subcarrier by 19 subcarriers.

11. The method of claim **8** wherein each cell-specific pilot of the cell-specific pilots is unique to a respective cell.

12. The method of claim **8** wherein the first plurality of subcarriers are not aligned in frequency with subcarriers of at least another cell onto which respective cell-specific pilots are inserted.

13. The method of claim **8** wherein the second plurality of subcarriers are beam-formed.

14. The method of claim **8** wherein the cell-specific pilots are used to convey cell-specific information.

15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:

at least one antenna; and

a receiver; and

the at least one antenna and the receiver are configured to:

receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and

receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and

recover cell-specific information using the cell-specific pilots;

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.

16. The OFDMA-compatible mobile station of claim **15** wherein all subcarriers of the first plurality of subcarriers are different than all subcarriers of the second plurality of subcarriers.

17. The OFDMA-compatible mobile station of claim **15** wherein the second plurality of subcarriers includes an n^{th} subcarrier and an n+18 subcarrier spaced apart from the n^{th} subcarrier by 17 subcarriers and the first plurality of subcarriers includes an m^{th} subcarrier and an m+20 subcarrier spaced apart from the m^{th} subcarrier by 19 subcarriers.

18. The OFDMA-compatible mobile station of claim **15** wherein each cell-specific pilot of the cell-specific pilots is unique to a respective cell.

19. The OFDMA-compatible mobile station of claim **15** wherein the first plurality of subcarriers are transmitted at a same time as the second plurality of subcarriers.

20. The OFDMA-compatible mobile station of claim **15** wherein the second plurality of subcarriers are beam-formed.

21. The OFDMA-compatible mobile station of claim **15** wherein the first plurality of subcarriers are not aligned in frequency with subcarriers of at least another cell onto which respective cell-specific pilots are inserted.

22. The OFDMA-compatible mobile station of claim **15** wherein the receiver is further configured to extract cell-specific information from the cell-specific pilots.

23. A method performed by an orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the method comprising:

receiving first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots;

receiving second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed;

recovering the data using channel estimates from at least the second pilots; and

recovering cell-specific information using the cell-specific pilots;

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.

24. The method of claim **23** wherein all subcarriers of the first plurality of subcarriers are different than all subcarriers of the second plurality of subcarriers.

25. The method of claim **23** wherein the second plurality of subcarriers includes an n^{th} subcarrier and an n+18 subcarrier spaced apart from the n^{th} subcarrier by 17 subcarriers and the first plurality of subcarriers includes an m^{th} subcarrier and an m+20 subcarrier spaced apart from the m^{th} subcarrier by 19 subcarriers.

26. The method of claim **23** wherein each cell-specific pilot of the cell-specific pilots is unique to a respective cell.

27. The method of claim **23** wherein the first plurality of subcarriers are transmitted at a same time as the second plurality of subcarriers.

28. The method of claim **23** wherein the second plurality of subcarriers are beam-formed.

29. The method of claim **23** wherein the first plurality of subcarriers are not aligned in frequency with subcarriers of at least another cell onto which respective cell-specific pilots are inserted.

30. The method of claim **23** further comprising extracting cell-specific information from the cell-specific pilots.

* * * * *

Exhibit 6

US010771302B2

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

(10) **Patent No.: US 10,771,302 B2**
(45) **Date of Patent: *Sep. 8, 2020**

(54) **CHANNEL PROBING SIGNAL FOR A BROADBAND COMMUNICATION SYSTEM**

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(73) Assignee: **Neo Wireless LLC**, Wayne, PA (US)

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

This patent is subject to a terminal disclaimer.

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(22) Filed: **Apr. 16, 2018**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H04L 12/26 (2006.01)
H04L 27/26 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 27/2626*** (2013.01); ***H04B 1/707*** (2013.01); ***H04B 1/711*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04L 12/26
(Continued)

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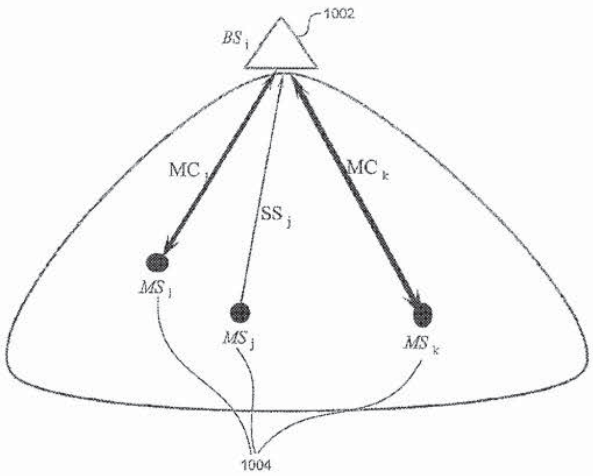
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Primary Examiner — Dimitry Levitan
(74) *Attorney, Agent, or Firm* — Volpe and Koenig, P.C.

(57) **ABSTRACT**

In a broadband wireless communication system, a spread spectrum signal is intentionally overlapped with an OFDM signal, in a time domain, a frequency domain, or both. The OFDM signal, which inherently has a high spectral efficiency, is used for carrying broadband data or control information. The spread spectrum signal, which is designed to have a high spread gain for overcoming severe interference, is used for facilitating system functions such as initial random access, channel probing, or short messaging. Methods and techniques are devised to ensure that the mutual interference between the overlapped signals is minimized to have insignificant impact on either signal and that both signals are detectable with expected performance by a receiver.

36 Claims, 18 Drawing Sheets



Related U.S. Application Data

continuation of application No. 13/861,942, filed on Apr. 12, 2013, now Pat. No. 8,767,522, which is a continuation of application No. 13/347,644, filed on Jan. 10, 2012, now Pat. No. 8,428,009, which is a continuation of application No. 12/975,226, filed on Dec. 21, 2010, now Pat. No. 8,094,611, which is a continuation of application No. 10/583,229, filed as application No. PCT/US2005/003518 on Jan. 27, 2005, now Pat. No. 7,864,725.

(60) Provisional application No. 60/540,586, filed on Jan. 30, 2004, provisional application No. 60/540,032, filed on Jan. 29, 2004.

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H04L 5/00	(2006.01)
H04L 25/03	(2006.01)
H04L 27/00	(2006.01)
H04B 1/707	(2011.01)
H04B 1/711	(2011.01)
H04L 25/02	(2006.01)

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

CPC ***H04L 5/0007*** (2013.01); ***H04L 5/0028*** (2013.01); ***H04L 25/03834*** (2013.01); ***H04L 27/0008*** (2013.01); ***H04L 27/0012*** (2013.01); ***H04L 27/2602*** (2013.01); ***H04L 27/2647*** (2013.01); *H04L 5/0016* (2013.01); *H04L 25/0228* (2013.01); *H04L 27/2607* (2013.01); *H04L 27/2655* (2013.01)

(58) **Field of Classification Search**

USPC 370/241, 252, 310, 328, 330, 464, 532

See application file for complete search history.

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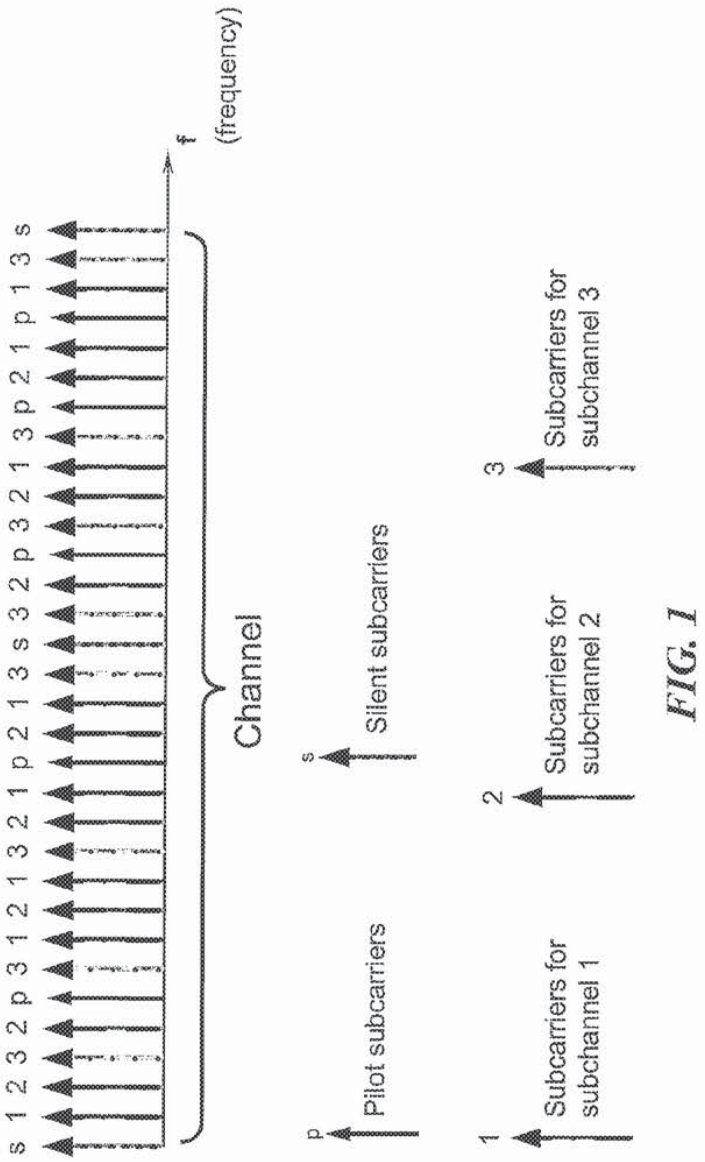

f
(frequency)
s 1 2 3 2 p 3 1 2 1 3 2 1 p 2 1 3 s 3 2 p 3 2 1 3 p 2 1 p 1 3 s
Channel
p
Pilot subcarriers
s
Silent subcarriers
1
Subcarriers for subchannel 1
2
Subcarriers for subchannel 2
3
Subcarriers for subchannel 3

FIG. 1



FIG. 2

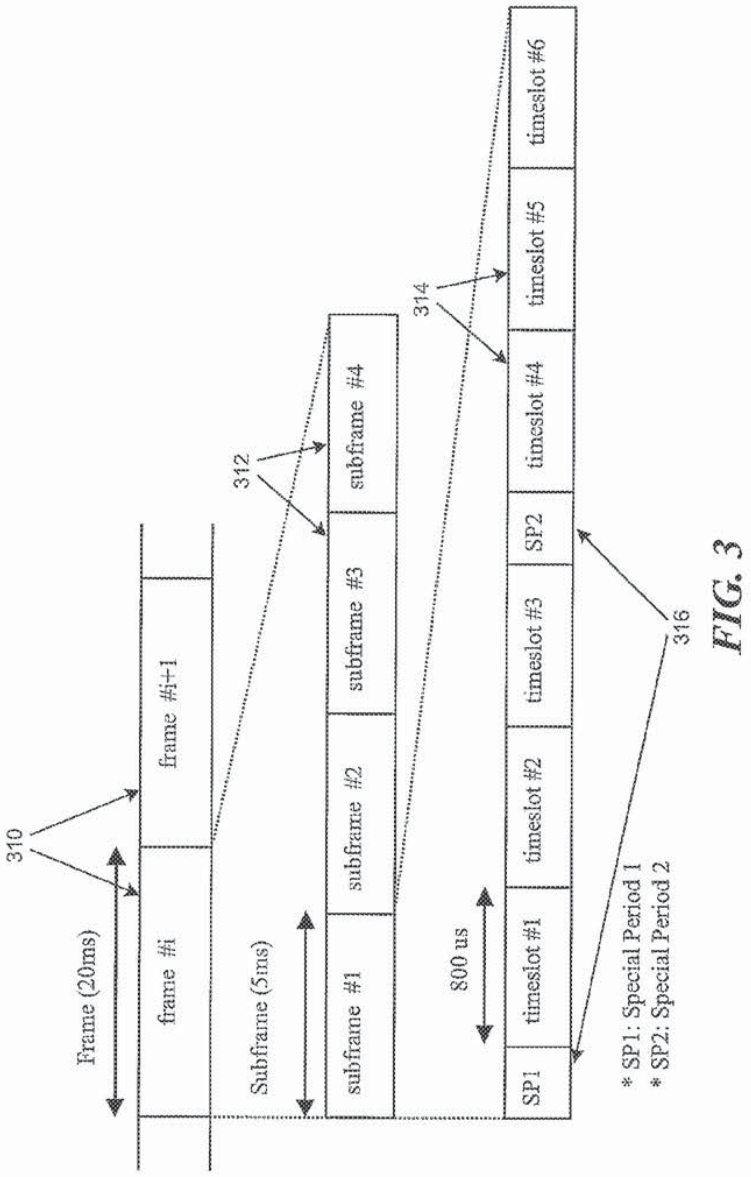

310
frame #i
frame #i+1
Frame (20ms)
312
subframe #1
subframe #2
subframe #3
subframe #4
Subframe (5ms)
314
800 us
SP1
timeslot #1
timeslot #2
timeslot #3
SP2
timeslot #4
timeslot #5
timeslot #6
316
* SP1: Special Period 1
* SP2: Special Period 2

FIG. 3

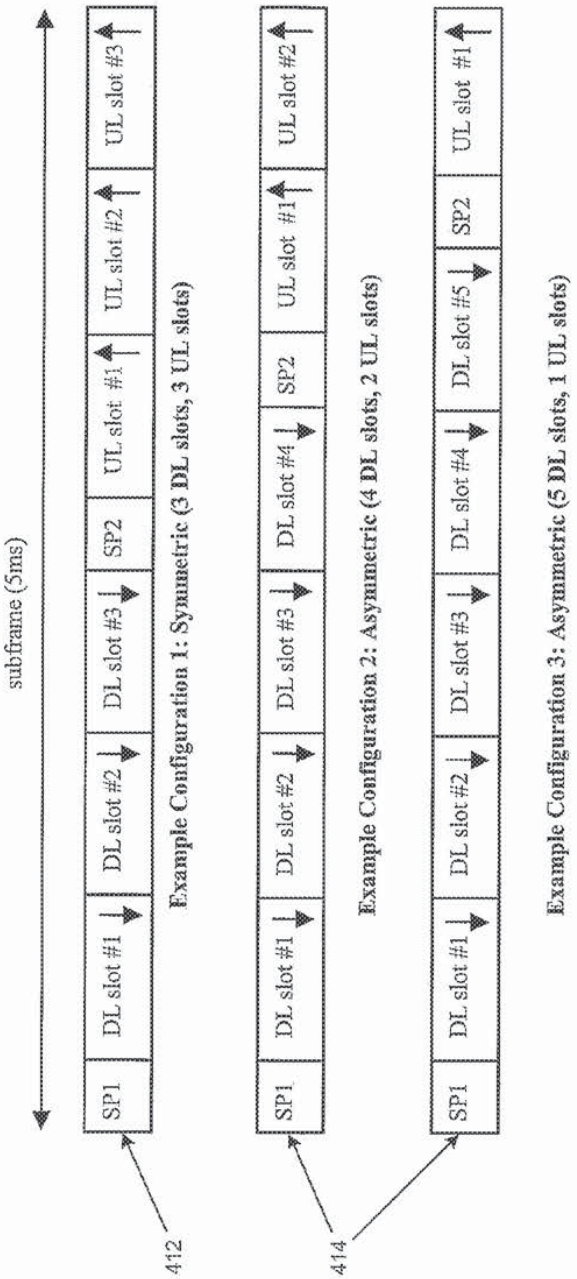

subframe (5ms)
SP1
DL slot #1
DL slot #2
DL slot #3
SP2
UL slot #1
UL slot #2
UL slot #3
Example Configuration 1: Symmetric (3 DL slots, 3 UL slots)
412
SP1
DL slot #1
DL slot #2
DL slot #3
DL slot #4
SP2
UL slot #1
UL slot #2
Example Configuration 2: Asymmetric (4 DL slots, 2 UL slots)
414
SP1
DL slot #1
DL slot #2
DL slot #3
DL slot #4
DL slot #5
SP2
UL slot #1
Example Configuration 3: Asymmetric (5 DL slots, 1 UL slots)

FIG. 4

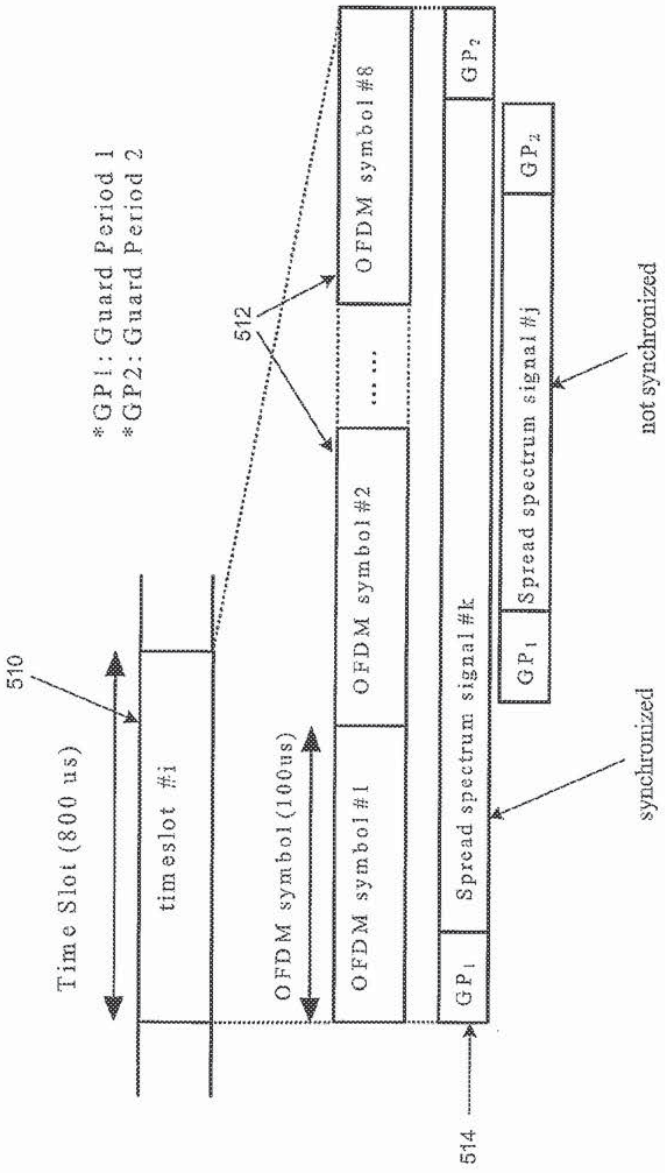

*GP1: Guard Period 1
*GP2: Guard Period 2
510
Time Slot (800 us)
timeslot #i
OFDM symbol (100us)
512
OFDM symbol#1
OFDM symbol#2
.....
OFDM symbol#8
GP1
Spread spectrum signal#k
GP2
GP1
Spread spectrum signal#j
GP2
synchronized
not synchronized
514

FIG. 5

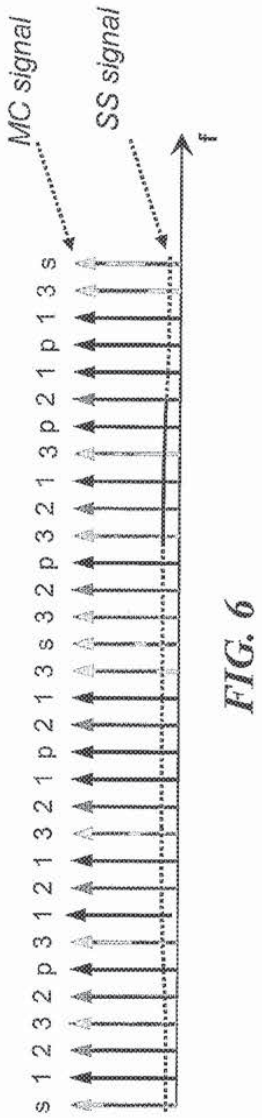


FIG. 6

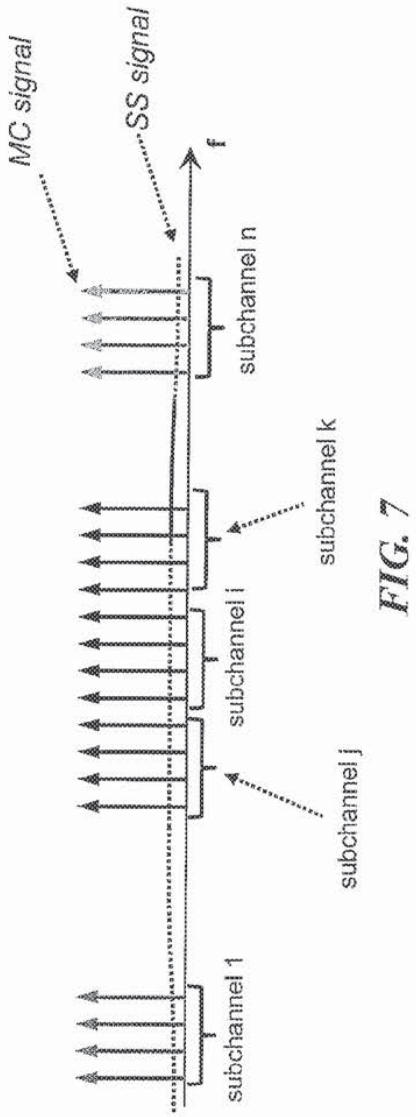

MC signal
SS signal
f
subchannel n
subchannel k
subchannel i
subchannel j
subchannel 1

FIG. 7

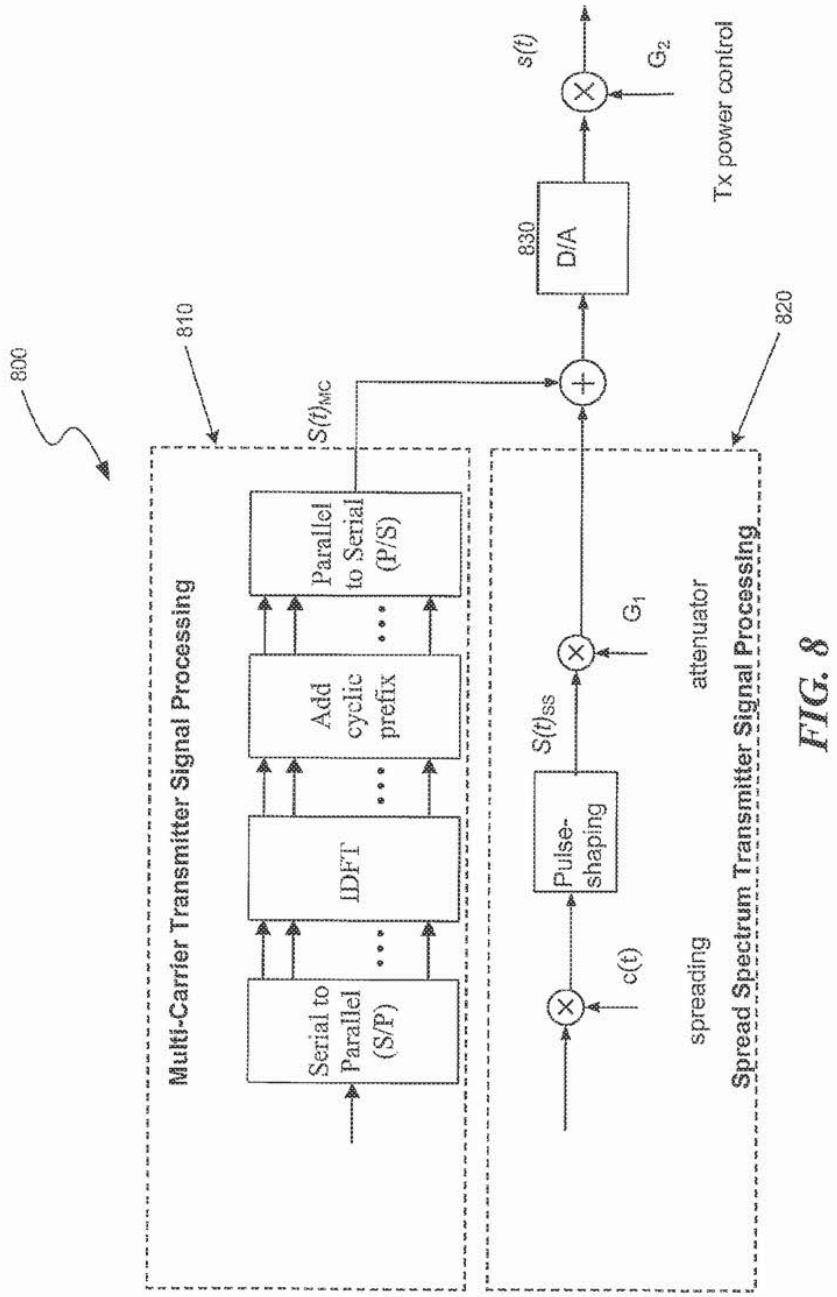

800
810
820
Multi-Carrier Transmitter Signal Processing
Serial to Parallel (S/P)
IDFT
Add cyclic prefix
Parallel to Serial (P/S)
S(t)MC
Spread Spectrum Transmitter Signal Processing
spreading
c(t)
Pulse-shaping
S(t)SS
attenuator
G1
Tx power control
D/A
830
s(t)
G2

FIG. 8

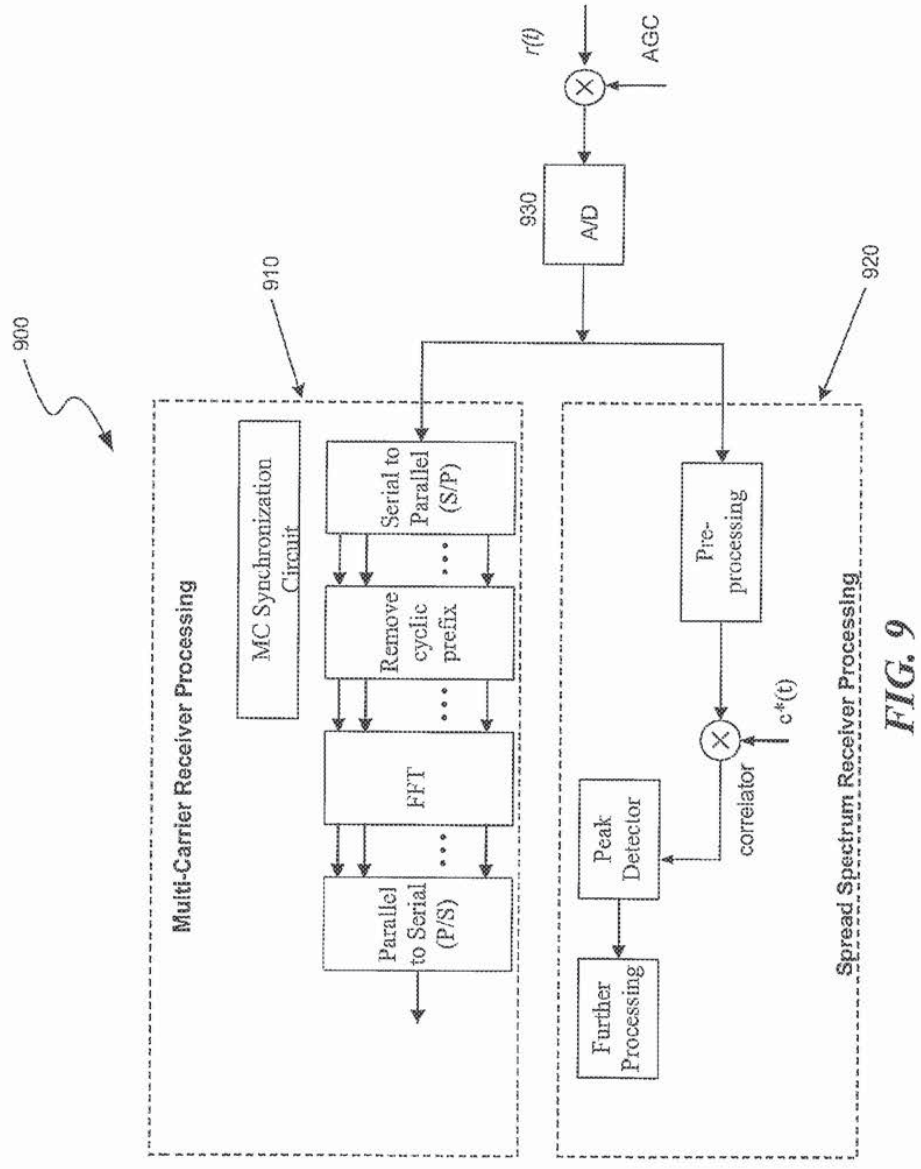

900
910
920
930
r(t)
AGC
A/D
Multi-Carrier Receiver Processing
MC Synchronization Circuit
Serial to Parallel (S/P)
Remove cyclic prefix
FFT
Parallel to Serial (P/S)
Spread Spectrum Receiver Processing
Pre-processing
c*(t)
correlator
Peak Detector
Further Processing

FIG. 9

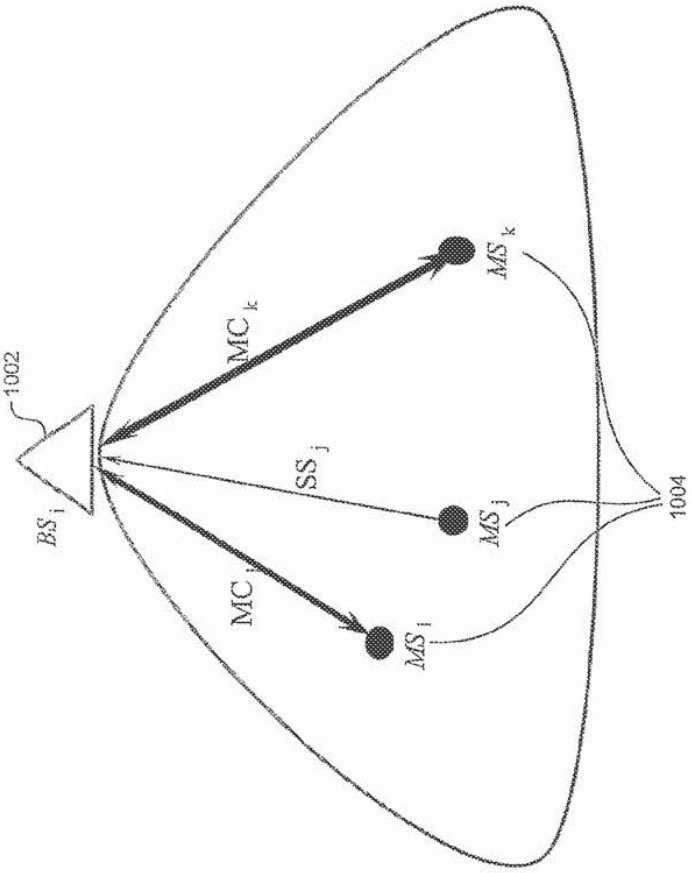


FIG. 10

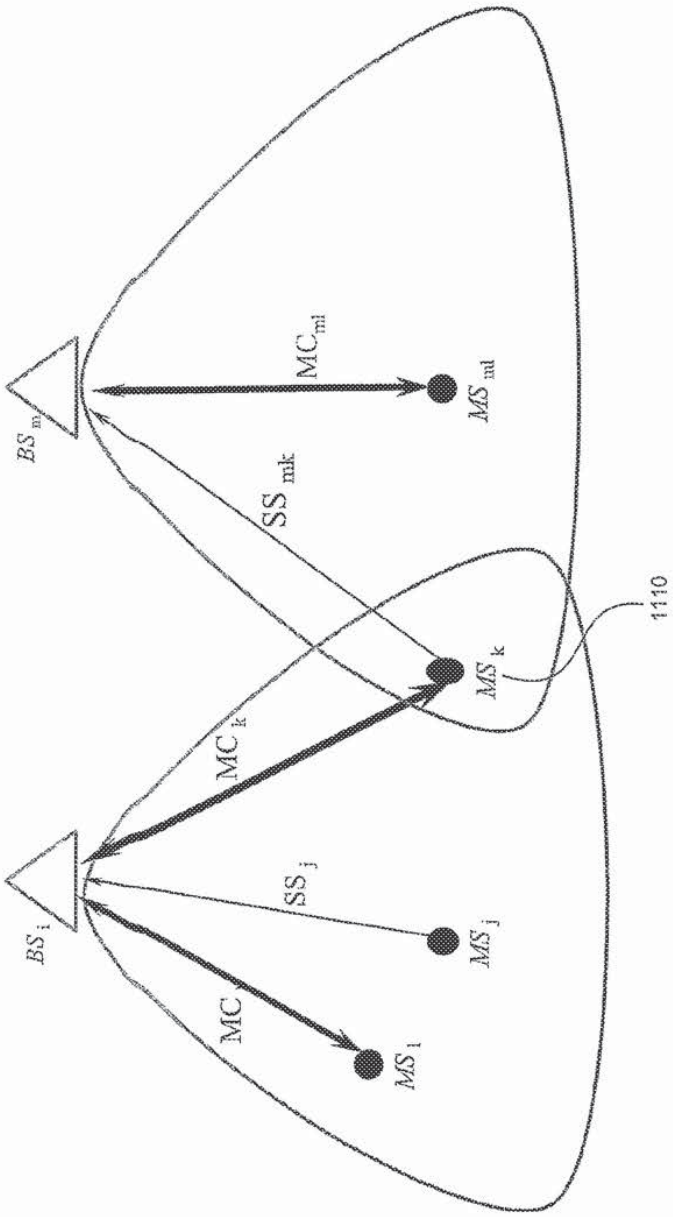


FIG. 11

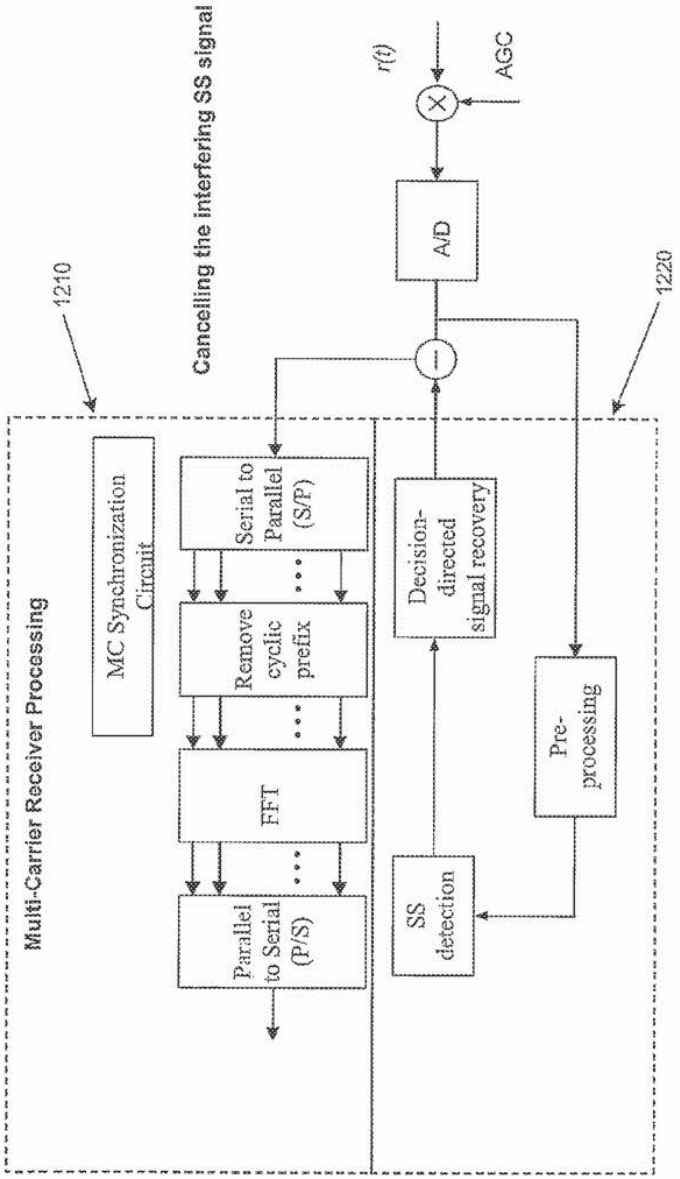

Cancelling the interfering SS signal
r(t)
AGC
A/D
1210
1220
Multi-Carrier Receiver Processing
MC Synchronization Circuit
Serial to Parallel (S/P)
Remove cyclic prefix
FFT
Parallel to Serial (P/S)
Decision-directed signal recovery
Pre-processing
SS detection

FIG. 12

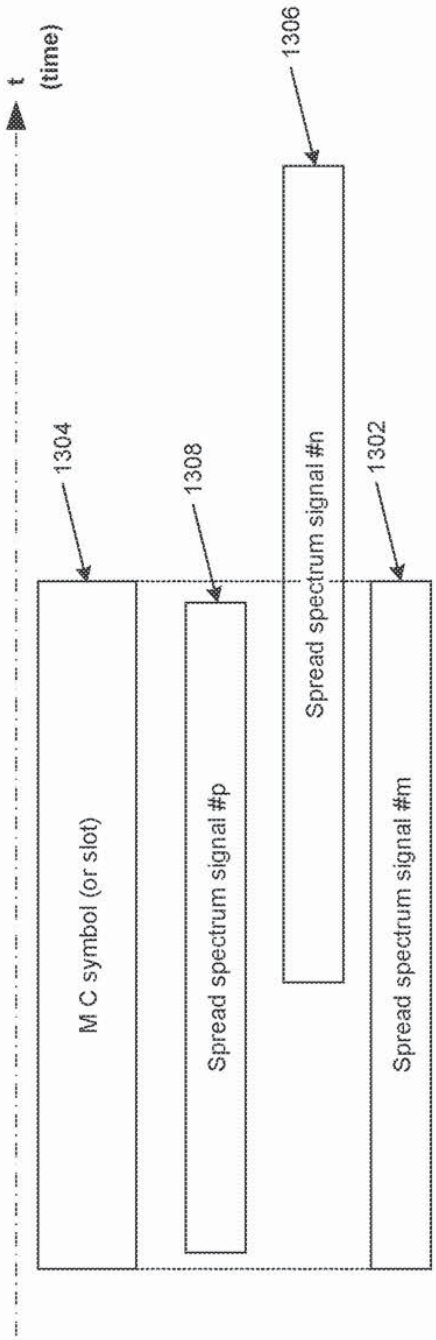

t
(time)
1306
1304
1308
1302
M C symbol (or slot)
Spread spectrum signal #p
Spread spectrum signal #n
Spread spectrum signal #m

FIG. 13

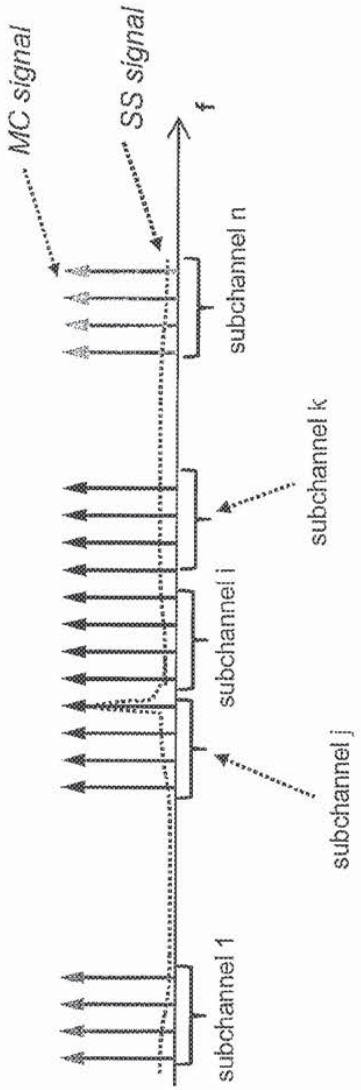

MC signal
SS signal
f
subchannel n
subchannel k
subchannel i
subchannel j
subchannel 1

FIG. 14

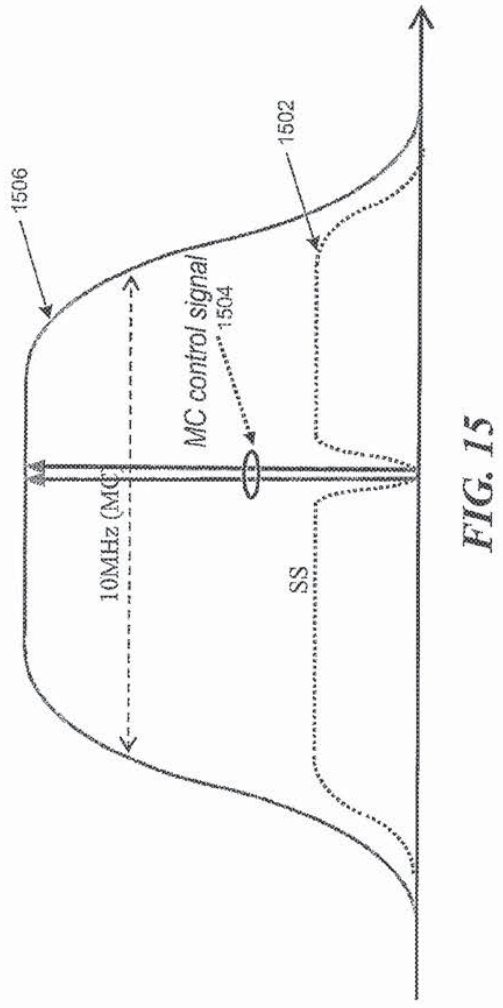


FIG. 15

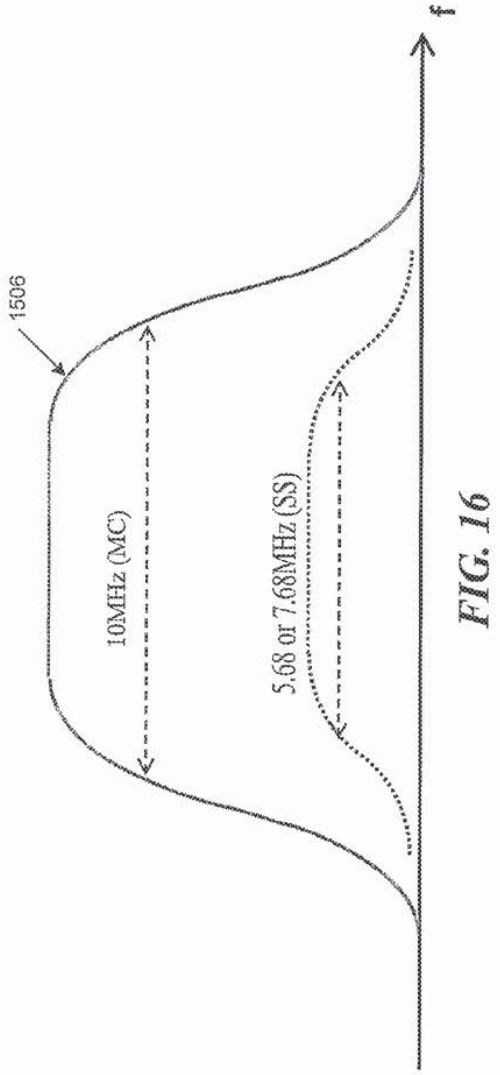


FIG. 16

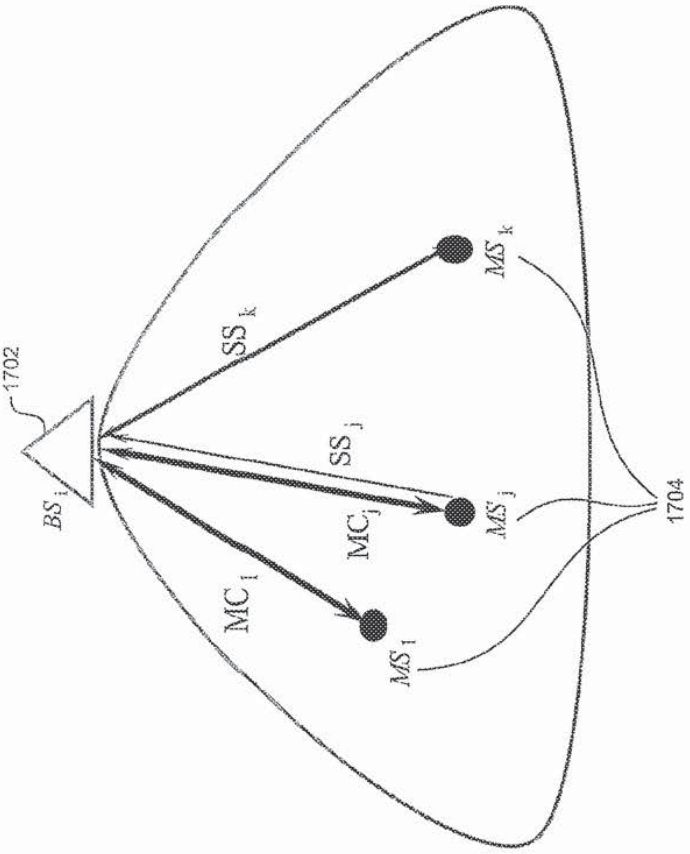


FIG. 17

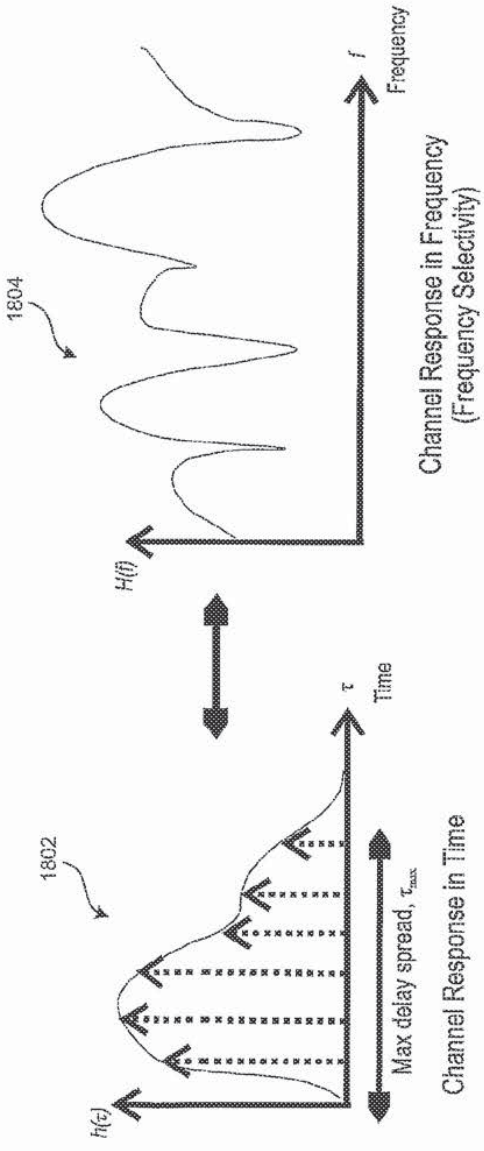

1804
H(f)
f
Frequency
Channel Response in Frequency
(Frequency Selectivity)
1802
h(τ)
τ
Time
Max delay spread, τ_{max}
Channel Response in Time

FIG. 18

CHANNEL PROBING SIGNAL FOR A BROADBAND COMMUNICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION (S)

This application is a continuation of U.S. patent application Ser. No. 14/321,615 (now U.S. Pat. No. 9,948,488), filed Jul. 1, 2014, which is a continuation application of U.S. patent application Ser. No. 13/861,942 (now U.S. Pat. No. 8,767,522), filed Apr. 12, 2013, which is a continuation application of U.S. patent application Ser. No. 13/347,644 (now U.S. Pat. No. 8,428,009), filed Jan. 10, 2012, which is a continuation application of U.S. patent application Ser. No. 12/975,226 (now U.S. Pat. No. 8,094,611), filed Dec. 21, 2010, all of which are incorporated herein by reference. U.S. patent application Ser. No. 12/975,226 is a continuation application of U.S. patent application Ser. No. 10/583,229 (now U.S. Pat. No. 7,864,725), filed Aug. 27, 2008, which is the National Stage Application of International Application No. PCT/US2005/003518, filed Jan. 27, 2005, which claims the benefit of U.S. Provisional Patent Application No. 60/540,586, filed on Jan. 30, 2004, and of U.S. Provisional Patent Application No. 60/540,032, filed on Jan. 29, 2004.

BACKGROUND

A direct Sequence Spread Spectrum (DSSS) system is inherently capable of supporting multi-cell and multi-user access applications through the use of orthogonal spreading codes. The initial access of the physical channel and frequency planning are relatively easier because of interference averaging in a DSSS system. It has been widely used in some existing wireless networks. However, a DSSS system using orthogonal spreading codes, may suffer severely from the loss of orthogonally in a broadband environment due to multi-path propagation effects, which results in low spectral efficiency.

In broadband wireless communications, Multi-Carrier (MC) technology is drawing more and more attention because of its capability. An MC system such as an Orthogonal Frequency Division Multiplexing (OFDM) system is capable of supporting broadband applications with higher spectral efficiency. An MC system mitigates the adverse effects of multi-path propagation in wireless environments by using cyclic prefixes to extend the signal period as the data is multiplexed on orthogonal sub-carriers. In effect, it converts a frequency selective channel into a number of parallel flat fading channels which can be easily equalized with simple one-tap equalizers. The modulator and the demodulator can be executed efficiently via the fast Fourier transform (FFT) with much lower cost. However, MC systems are vulnerable while operating in multi-user and multi-cell environments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers.

FIG. **2** illustrates a radio resource being divided into small units in both frequency and time domains.

FIG. **3** illustrates a frame structure of an exemplary OFDM system.

FIG. **4** illustrates three examples of a subframe structure in the exemplary OFDM system.

FIG. **5** illustrates slot structure of the OFDM system and the overlay system.

FIG. **6** is an illustration of MC signals overlaid with DSSS signals in the frequency domain where the power level of the DSSS signal is much lower than that of the MC signal.

FIG. **7** is same as FIG. **6** wherein not all MC subchannels are occupied.

FIG. **8** illustrates a transmitter structure of MC and DSSS overlay system.

FIG. **9** illustrates a receiver structure of MC and DSSS overlay system.

FIG. **10** illustrates examples of communications between a base station and multiple mobile stations transmitting DSSS and MC signals.

FIG. **11** illustrates a mobile station sending DSSS signals to its current serving base station, or other base stations.

FIG. **12** illustrates using interference cancellation technique to cancel interfering DSSS signal in a composite signal to obtain a clearer MC signal.

FIG. **13** illustrates a DSSS signal and a MC signal fully overlaid or partially overlaid at MC symbol or slot boundary in time domain.

FIG. **14** illustrates a DSSS signal with a high Peak to Average Ratio in frequency domain causing strong interference to certain MC subcarriers.

FIG. **15** illustrates using spectrum nulls in DSSS signal to protect an MC control subchannel.

FIG. **16** illustrates spectrum control for DSSS signal using simple sub-sampling method.

FIG. **17** illustrates examples of communications between a base station and multiple mobile stations transmitting both DSSS and MC signals.

FIG. **18** illustrates a typical channel response in the time and frequency domains. By estimating the peaks of a channel response in the time domain, the channel profile in the frequency domain can be obtained.

DETAILED DESCRIPTION

A broadband wireless communication system where both the Multi-Carrier (MC) and direct Sequence Spread Spectrum (DSSS) signals are intentionally overlaid together in both time and frequency domains is described. The system takes advantage of both MC and DSSS techniques to mitigate their weaknesses. The MC signal is used to carry broadband data signal for its high spectral efficiency, while the DSSS signal is used for special purpose processing, such as initial random access, channel probing, and short messaging, in which signal properties such as simplicity, self synchronization, and performance under severe interference are of concern. In the embodiments of this invention both the MC and the DSSS signals are distinguishable in normal operations and the interference between the overlaid signals is insufficient to degrade the expected performance of either signal.

Unlike a typical CDMA system where the signals are designed to be orthogonal in the code domain or an OFDM system where the signals are designed to be orthogonal in frequency domain, the embodiments of this invention overlay the MC signal, which is transmitted without or with very low spreading, and the DSSS signal, which is transmitted at a power level lower than that of the MC signal.

In accordance with aspects of certain embodiments of this invention, the MC signal is modulated on subcarriers in the frequency domain while the DSSS signal is modulated by the information bits or symbols in the time domain. In some cases the information bits modulating the DSSS sequence are always one.

This invention further provides apparatus and means to implement the mentioned processes and methods in a broadband wireless multi-access and/or multi-cell network, using advanced techniques such as transmit power control, spreading signal design, and iterative cancellation.

The mentioned MC system can be of any special format such as OFDM or Multi-Carrier Code Division Multiple Access (MC-CDMA). The presented methods and apparatus can be applied to downlink, uplink, or both, where the duplexing technique can be either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

Various embodiments of the invention are described to provide specific details for thorough understanding and enablement; however, the aspects of the invention may be practiced without such details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the essential matters.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

Multi-Carrier Communication System

The physical media resource (e.g., radio or cable) in a multi-carrier communication system can be divided in both the frequency and time domains. This canonical division provides a high flexibility and fine granularity for resource sharing.

The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. Within a particular spectral band or channel, there are a fixed number of subcarriers. There are three types of subcarriers:

1. Data subcarriers, which contain information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are employed for assisting system functions such as estimation of system parameters; and
3. Silent subcarriers, which have no energy and are used for guard bands and DC carrier.

FIG. **1** illustrates a basic structure of a multi-carrier signal in the frequency domain, made up of subcarriers. The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The carriers forming one subchannel are not necessarily adjacent to each other. As depicted in FIG. **1**, each user may use part or all of the subchannels.

FIG. **2** illustrates a radio resource being divided into small units in both frequency (subchannels) and time domains (time slots). The basic structure of an MC signal in the time domain is made up of time slots to support multiple-access.

An Exemplary MC System

An OFDM system is used in the system as a special case of an MC system. The system parameters for the uplink under consideration are listed in Table 1. FIG. **3** illustrates a frame structure of a suitable OFDM system. In this system, a 20 ms frame **310** is divided into four 5 ms subframes **312**. One subframe **312** consists of six time slots **314** and two special periods **316**, which serve transition time from downlink to uplink and vise versa. The six time slots in one subframe can be configured as either uplink or downlink slots symmetrically or asymmetrically.

FIG. **4** illustrates three examples of a subframe structure in an OFDM system: one symmetric configuration **412** and two asymmetric configurations **414**, each with differing number of uplink (UL) and downlink (DL) slots. FIG. **5** illustrates a slot structure of an OFDM system and an overlay system. One 800 μs time slot **510** is comprised of 8 OFDM symbols **512**, which are overlaid by DSSS signals **514** in the time domain. Two guard periods GP**1** and GP**2** are allocated for the DSSS signal **514**.

TABLE 1

Uplink system parameters	
Data Rate	2, 4, 8, 16, 24 Mbps
Modulation	QPSK, 16-QAM
Coding rate	1/8, 1/4, 1/2, 3/4
IFFT/FFT size	1024
OFDM symbol duration	100 us
Guard interval	11.11 us
Subcarrier spacing	9.765625 kHz
System sampling rate (fs)	11.52 MHz
Channel spacing	10 MHz

Detailed Description of a MC and DSSS Overlay System

FIG. **5** illustrates the overlay of the MC and DSSS signals, where the DSSS signal overlaps with the MC signal in the time domain. The overlaid signal can be aligned at the boundary of MC slot or MC symbol when they are synchronized (for example, DSSS signal #k in FIG. **5**). It can also be not aligned when they are not synchronized (for example, DSSS signal #j in FIG. **5**). In one embodiment, the DSSS signal is placed at the period of cyclic prefix of the OFDM symbol.

FIG. **6** is an illustration of MC signals overlaid with DSSS signals in the frequency domain where the power level of the DSSS signal is much lower than that of the MC signal. The subcarriers in a subchannel are not necessarily adjacent to each other in the frequency domain. FIG. **7** is similar to FIG. **6** wherein not all MC subchannels are occupied. It illustrates a scenario where some MC subchannels are not energized.

In another embodiment, the MC signal is modulated on subcarriers in the frequency domain while the DSSS signal is modulated in either the time domain or the frequency domain. In one embodiment the modulation symbol on the DSSS sequence is one and the sequence is unmodulated.

FIG. **8** illustrates a transmitter structure **800** of an MC and DSSS overlay system, wherein the MC signal and DSSS signal are added together prior to Digital to Analog (D/A) conversion **830**. In FIG. **8**, the top branch **810** is an OFDM transmitter and the bottom branch **820** is the spread spectrum transmitter. In the MC transmitter, the S/P buffer converts the sequential inputs into parallel outputs, which are in turn inputted to the inverse discrete Fourier transform (IDFT). The outputs from the IDFT are the time domain signals, which are converted from parallel to sequential signals after a cyclic prefix is added. Adding the prefix can also be performed after the P/S conversion. In the spread spectrum transmitter, the DSSS sequence is modulated by the information bits or symbols and the modulated signals will undergo pulse-shaping filtering so that the signal spectrum meets specified criteria.

A digital attenuator (G**1**) is used for the DSSS signal to adjust its transmitted signal level relative to the MC signal.

The two signals are overlaid in the digital domain before converting to a composite analog signal. A second analog variable gain (G**2**) is used subsequent to the D/A converter **830** to further control the power level of the transmitted signal. When the MC signal is not present, both G**1** and G**2** will be applied to the DSSS signal to provide sufficient transmission dynamic range. G**2** can be realized in multiple circuit stages.

FIG. **9** illustrates a receiver structure **900** of an MC and DSSS overlay system. A composite signal is processed by a MC receiver **910** and DSSS receiver **920**. At the receiver side, after automatic gain control (AGC), an Analog-to-Digital (A/D) converter **930** converts the received analog signal to digital signal. The MC receiver basically performs a reverse process of the MC transmitter. The MC synchronization circuit carries out the synchronization in both time and frequency for the receiver to function properly. The outputs of the P/S are information bits or symbols. To detect whether a DSSS signal is present, the signal is despread with a matched filter or a correlator, using the access sequence, to check if the correlation peak exceeds a predefined threshold. The information from the DSSS receiver **920** will then be used to decode the mobile station's signature in the case of initial random access; to derive the channel information in the case of channel probing; or to decode the information bit in the case of short messaging.

In one embodiment a rake receiver is used in the DSSS receiver **920** to improve its performance in a multi-path environment. In another embodiment, the MC signal is processed as if no DSSS signal is present. In yet another embodiment, advanced interference cancellation techniques can be applied to the composite signal to cancel the DSSS signal from the composite signal thus maintaining almost the same MC performance.

The transmitted composite signal for user i can be represented by:

$$s_i(t)=G_{i,2}*[G_{i,1}*s_{i,SS}(t)+b_i*s_{i,MC}(t)] \quad (1)$$

where bi is 0 when there is no MC signal and is 1 when an MC signal is present. Similarly, $G_{i,1}$ is 0 when there is no DSSS signal and varies depending on the power setting of the DSSS signal relative to the MC signal when a DSSS signal is present. $G_{i,2}$ is used to control the total transmission power for user i. The received signal can be represented by:

$$r(t) = \sum_{i=1}^{M} s_i(t) + N + I \quad (2)$$

where M is the total number of mobile station actively communicating with the current base station, N is the Gaussian noise, and I is the total interference from all the mobile stations in current and other base stations.

Denoting the received power of the MC signal as P_{MC} and the received power of the DSSS signal as P_{SS}, the signal to interference and noise ratio (SINR) for the MC signal is:

$$SINR_{MC}=P_{MC}/(N+I) \quad (3)$$

when the DSSS signal is not present; and is

$$SINR'_{MC}=P_{MC}/(N+I+P_{SS}) \quad (4)$$

when the DSSS signal is present. The system is designed such that the $SINR'_{MC}$ meets the SINR requirement for the MC signal and its performance is not compromised in spite of interference from the overlaid DSSS signal.

In one embodiment, the DSSS signal is power controlled such that P_{SS} is well below the noise level, N.

On the other hand, the SINR for the DSSS signal is

$$SINR'_{SS}=P_{SS}/(N+I+P_{MC}) \quad (5)$$

Denoting the spreading factor for the DSSS signal as K_{SF}, the effective SINR for one symbol after despreading is:

$$SINR'_{SS}=P_{SS}*K_{SF}/(N+I+P_{MC}) \quad (6)$$

$SINR'_{SS}$ must be high enough to meet the performance requirement when detecting or decoding the information conveyed in the DSSS signal. In one embodiment, K_{SF} is chosen to be 1000, so that the DSSS signal is boosted with 30 dB spreading gain after despreading.

FIG. **11** illustrates a mobile station **1110** sending DSSS signals to its current serving base station or other base stations. The latter case is especially helpful in hand-off processes. In this Figure, a mobile station MS_k is communicating with a BS_i using an MC signal while transmitting a DSSS signal to BS_k.

Power Control

As discussed above, one design issue is to minimize the power of the DSSS signal to reduce its interference with the MC data signal. In one embodiment, the initial power setting of a mobile station, T_{MS_tx} (in dBm), is set based on path loss, L_{path} (in dB), and the desired received power level at the base station, $P_{BS\_rx\_des}$ (in dBm),

$$T_{MS\_tx}=P_{BS\_rx\_des}+L_{path}-C_1-C_2 \quad (7)$$

C_1 (in dB) is set to a proper value so that the SINR of the MC as specified in equation (4) meets its requirement. C_2 (in dB) is an adjustment to compensate for the power control inaccuracy. Open loop power control inaccuracy is mainly caused by a discrepancy between an estimated path loss by the mobile station and the actual path loss.

In one embodiment, C_1 is set to 9 dB for MC using QPSK modulation with ½ error control coding or 15 dB for MC using 16 QAM modulation with ½ error control coding. C_2 is set to 10 dB or 2 dB depending on whether the mobile station is under open loop power control or closed loop power control. Power control for the DSSS signal also eases the spectrum mask requirement for the DSSS signal because the DSSS signal level is much lower than that of the MC signal.

With total power offset of C_1+C_2 subtracted from an initial transmission power of the DSSS signal, the spreading factor of the DSSS signal needs to be set high enough (e.g., 512 (27 dB) or higher) so that the DSSS signal can be detected in normal conditions. This requires a sufficient number of bits of the A/D converter at the base station, for example, 12 bits.

In one embodiment, the D/A converter at the mobile station uses 12 bits, among which 8 bits are targeted for the MC signal (assuming 3 bits are reserved for MC peak to average consideration). Thus, there are enough bits left for the DSSS signal even with significant attenuation relative to the MC signal.

Canceling the Interference of DSSS Signal to the MC Signal

In one embodiment, the base station employs interference cancellation techniques to cancel the DSSS interference to the MC signal. FIG. **12** illustrates a system for using an interference cancellation technique to cancel an interfering DSSS signal in a composite signal to obtain a clearer MC signal. First, a DSSS signal is detected by the DSSS receiver **1220**; then it is subtracted (decision directed) from the total received signal to obtain a cleaner MC data signal in the MC receiver **1210**, as illustrated in FIG. **12**. In another embodi-

ment, multiple step iterative cancellation can be applied to further improve the effectiveness of the interference cancellation. The MC receiver basically performs a reverse process of the MC transmitter mentioned above. The MC synchronization circuit carries out the synchronization in both time and frequency for the receiver to function properly. The outputs of the P/S are information bits or symbols.

DSSS Signal Design

DSSS sequences are chosen to have good autocorrelation and cross-correlation properties (i.e., with high peak to sidelobe ratio). In one embodiment, pulse-shaping is applied to restrict the spectrum mask of DSSS signals and to reduce impacts on the MC signals in the frequency domain. For example, the transmitter pulse-shaping filter applied to the DSSS signal can be a root-raised cosine (RRC) with roll-off factor a in the frequency domain. The impulse response of the chip impulse filter $RC_0(t)$ is

$$RC_0(t) = \frac{\sin\left(\pi \frac{t}{T_C}(1-\alpha)\right) + 4\alpha \frac{t}{T_C}\cos\left(\pi \frac{t}{T_C}(1+\alpha)\right)}{\pi \frac{t}{T_C}\left(1-\left(4\alpha \frac{t}{T_C}\right)^2\right)} \quad (8)$$

where T_c is the chip duration.

FIG. **13** illustrates a DSSS signal and a MC signal fully overlaid or partially overlaid with an MC symbol or slot boundary in the time domain. The DSSS and the MC signals may be aligned at the symbol (or slot) boundary when they are synchronized, or partially overlapped in the time domain when they are not synchronized, as shown in FIG. **13**, where a DSSS signal #m **1302** fully overlaps with a MC symbol (or slot) **1304** in time domain, while a DSSS signal #n **1306** overlaps with the MC symbol (or slot) only partially.

FIG. **14** illustrates a DSSS signal with a high Peak to Average Ratio in the frequency domain causing strong interference to certain MC subcarriers. The sequence used to spread the DSSS signal has to be designed to avoid cases where the DSSS signal may have a high Peak to Average ratio (PAR) in the frequency domain and its spikes may cause severe interference with some MC subcarriers, as illustrated in FIG. **14**. In one embodiment, the DSSS sequence is designed so that, in partial or in full, it has low PAR in the frequency domain using signal processing techniques, such as a PAR reduction algorithm. Either binary or non binary sequences can be used.

In another embodiment, Golay complementary sequences, Reed-Muller codes, or the codes designed with similar construction methods may be used to control the PAR of DSSS sequences in the frequency domain, thereby limiting the interference of DSSS signals to MC signals, which are demodulated in the frequency domain. In one embodiment, guard periods are added to the DSSS signal which overlaps with one MC symbol, as shown by DSSS signal #p **1308** in FIG. **13**. The guard periods ensure that a well-designed DSSS sequence (with low PAR in frequency domain) causes little interference with the MC subcarriers even when there is time misalignment in a DSSS signal relative to the OFDM symbol period.

Within MC subcarriers, the control subcarriers are more important than the data subcarriers and may need to have a better protection in the overlay system.

FIG. **15** illustrates using spectrum nulls in the DSSS signal **1502** to protect an MC control subchannel. In one embodiment, the DSSS sequence is designed to have spectrum nulls at MC control subchannels to avoid excess interference with the uplink MC control signals **1504**, as illustrated in FIG. **15**. One such scheme is to use subsampling such that the chip rate of the DSSS signal is ½ or ⅔ of the system sampling rate, which means the DSSS spectrum will only occupy the center portion with a width of 5.76 MHz or 7.68 MHz out of the 10 MHz available spectrum **1506**, as shown in FIG. **16**. Its interference with the MC sub-carriers over the rest of the spectrum will be much lower where the MC subchannels, carrying control information or using higher modulation subcarriers (such as 16 QAM), are placed.

Initial Random Access Using the Overlay Scheme

FIG. **10** illustrates a DSSS signal used as initial random access by the mobile station MS_j **1004**, in an overlay system. In the mean time, MS_j and MS_k are transmitting MC signals to the base station BS_i **1002**. In one embodiment of the invention, the DSSS signal is used for initial random access and the MC signal is used by multiple mobile stations to transmit high rate data and related control information, as illustrated in FIG. **10**. In this arrangement the mobile station MS_j is transmitting its initial access DSSS signal simultaneously with the MC signals from other mobile stations (in this case, MS_j and MS_K) to the base station BS_i.

In the initial random access of a multi-carrier multiple access system, a mobile station cannot transmit directly onto the control subchannel because its transmission time and power have not been aligned with other mobile stations. When this mobile station powers up or wakes up from a sleep mode, it first listens to a base station broadcasting channel and finds an available random access DSSS channel. It then sends an initial random access signal over the DSSS channel with a certain signature code or sequence that is designated to the corresponding base station and is broadcasted to all the mobile stations by each base station.

The initial access DSSS signal arrives at the base station together with MC signals from other mobile stations, each carrying data and control information. The initial power level of the DSSS signal is based on the open power loop control settings. A sufficient guard period is reserved in the DSSS signal to account for initial time alignment uncertainty, as shown in FIG. **5**.

If the base station successfully detects the DSSS signal, it sends the acknowledgement (ACK) carrying information such as a signature or other unique mobile station identifier and power and time adjustments of the mobile on the downlink control channel in the next available timeslot. The mobile station whose transmission signature matches that of the acknowledgement then moves to the designated uplink MC control channel using the assigned time and power values and further completes the message transmission.

If no feedback is received at the mobile station after a pre-defined number of slots, it assumes that the access slot was not detected by the base station, and will ramp up the transmission power of the DSSS signal by one step and re-transmit it, until it reaches the maximum allowable transmit signal power or the maximum retry times. In one embodiment, the power ramping step of the mobile station is set to be 1 dB or 2 dB which is configured by the base station on the downlink broadcasting channel. The maximum allowable transmit signal power and the retry times are also controlled by the base station depending on the uplink modulation/coding scheme and available access channels. During the initial random access, the DSSS signal can also be used for channel probing and short messaging.

Channel Probing Using DSSS in the Overlay System

In one embodiment of the invention, the DSSS signal is used to assist estimation of channel characteristics. In this

case, the mobile station is already synchronized in time and frequency with the base station, and its transmission of the MC signal is under closed-loop power control with the base station.

FIG. **17** illustrates examples of communications between a base station **1702** and multiple mobile stations **1704** transmitting both DSSS and MC signals. DSSS signal is used for channel probing or to carry short messages. In this case, MS_j **1704** is transmitting both an MC signal and a DSSS signal to the base station BS_i **1702**. It is also under closed loop power control with the base station BS_i **1702**. In FIG. **17**, the mobile station MS_j **1704** is transmitting its DSSS signal simultaneously with its own MC signal. Other mobile stations (in this case, MS_l **1704** and MS_K **1704**) are transmitting either MC or DSSS signals to the base station BS_i **1702**.

FIG. **18** illustrates a typical channel response in the time domain **1802** and the frequency domain **1804**. By estimating the peaks of a channel response in the time domain **1802**, the channel profile in the frequency domain **1804** can be obtained. A typical channel response in the time domain and frequency domain for a broadband wireless system is shown in FIG. **18**. Using a matched filter in the DSSS receiver at the base station, the peaks of a channel response in time can be detected.

When closed loop power control is used, the initial power settings will be much more accurate than by using open loop power control alone. Thus, the margin reserved for power control inaccuracy can be reduced to a much smaller value. Furthermore, a bigger spreading factor can be used since no data information needs to be conveyed in the DSSS signal. This leaves a dynamic range large enough for detecting multi-path peaks from the output of the match filter or correlator, thereby generating a better channel profile. When and how often a mobile station should send the DSSS signal for channel probing is configurable by the network or the mobile station.

In one embodiment, the base station dictates the mobile station to transmit the channel probing DSSS when it needs an update of the mobile station's channel characteristics. In another embodiment, the base station polls the mobile station during its silent period and gets an update of the mobile station's information such as transmission timing and power from the probing DSSS signal. In yet another embodiment, the channel profile information is used by the base station to determine the proper modulation/coding and pilot pattern. In yet another embodiment, the channel profile information is used for advanced antenna techniques such as beamforming. In one embodiment, channel probing with the DSSS signaling is performed without close loop power control or time synchronization.

Short Message Using DSSS in the Overlay System

In one embodiment of the invention, the DSSS signal is used to carry short messages. In this case, the mobile station is already synchronized in time and frequency with the base station, and its transmission of a MC signal is also under closed-loop power control with the base station. As shown in FIG. **17**, the mobile station MS_j is transmitting its DSSS signal carrying a short message simultaneously with its own MC signal. Other mobile stations (in this case, MS_l and MS_K) are transmitting either the MC signal or DSSS signal to the base station BS_i. In this case, the short message carried by the DSSS signal has a much lower data rate compared with that of the MC signal. In another embodiment, short messaging using the DSSS signaling is performed without close loop power control or time synchronization.

The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

Changes can be made to the invention in light of the above "Detailed Description." While the above description details certain embodiments of the invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Therefore, implementation details may vary considerably while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.

We claim:

1. A communication method for a mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the method comprising:

receiving a request for a probing signal from a base station in the system; and

transmitting, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:

the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and

the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.

2. The method of claim **1**, wherein the probing signal provides information for the base station to estimate a channel profile in the frequency domain.

3. The method of claim 2, wherein the mobile device receives a subsequent transmission from the base station that has been beamformed using the estimated channel profile.

4. The method of claim 1, wherein the probing signal provides information for the base station to determine a transmission format for a subsequent transmission.

5. The method of claim 4, wherein the transmission format comprises a modulation/coding or pilot pattern.

6. The method of claim 1, wherein the portion of spectrum is available for transmission of uplink data signals by other mobile devices in the system during a time period when the portion of the spectrum is not occupied by the probing signal.

7. The method of claim 1, wherein the portion of spectrum is within a center portion of the uplink frequency band and subcarriers for the transmission of uplink control signals are within an outer portion of the uplink frequency band.

8. A communication method for a base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the method comprising:

transmitting a request for a probing signal to a mobile device in the system; and

receiving the probing signal from the mobile device, wherein:

the probing signal contains a code sequence modulated in the frequency domain;

the probing signal overlaps, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and

the probing signal occupies a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.

9. The method of claim 8, further comprising estimating, based on the received probing signal, a channel profile in the frequency domain.

10. The method of claim 9, further comprising using the channel profile to determine a transmission format for a subsequent transmission over the channel.

11. The method of claim 10, wherein the transmission format comprises a modulation/coding or pilot pattern.

12. The method of claim 9, further comprising using the channel profile for beamforming in a subsequent transmission to the mobile device.

13. The method of claim 8, wherein the portion of spectrum is available for transmission of uplink data signals by other mobile devices in the system during a time period when the portion of the spectrum is not occupied by the probing signal.

14. The method of claim 8, wherein the portion of spectrum is within a center portion of the uplink frequency band and subcarriers for the transmission of uplink control signals are within an outer portion of the uplink frequency band.

15. A communication method for an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the method comprising:

sending a request for a probing signal to a mobile device from a base station in the system; and

responding by the mobile device to the request by transmitting the probing signal with a code sequence modulated in the frequency domain, wherein:

the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and

the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.

16. The method of claim 15, wherein transmission power of the probing signal is under power control.

17. The method of claim 15, wherein the probing signal enables the base station to estimate a channel profile in the frequency domain.

18. The method of claim 17, wherein the channel profile is used by the base station to determine a transmission format for a subsequent transmission.

19. The method of claim 18, wherein the transmission format comprises a modulation/coding or pilot pattern.

20. The method of claim 17, wherein the channel profile is used for beamforming in a subsequent transmission by the base station to the mobile device.

21. The method of claim 15, wherein the portion of spectrum is available for transmission of uplink data signals by other mobile devices in the system during a time period when the portion of the spectrum is not occupied by the probing signal.

22. The method of claim 15, wherein the portion of spectrum is within a center portion of the uplink frequency band and subcarriers for the transmission of uplink control signals are within an outer portion of the uplink frequency band.

23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:

a receiver configured to receive a request for a probing signal from a base station in the system;

a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:

the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and

the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.

24. The mobile device of claim 23, wherein the probing signal provides information for the base station to estimate a channel profile in the frequency domain.

25. The mobile device of claim 24, wherein the mobile device is configured to receive a subsequent transmission from the base station that has been beamformed using the estimated channel profile.

26. The mobile device of claim 23, wherein the probing signal provides information for the base station to determine a transmission format for a subsequent transmission.

27. The mobile device of claim 26, wherein the transmission format comprises a modulation/coding or pilot pattern.

28. The mobile device of claim 23, wherein the portion of spectrum is available for transmission of uplink data signals by other mobile devices in the system during a time period when the portion of the spectrum is not occupied by the probing signal.

29. The mobile device of claim 23, wherein the portion of spectrum is within a center portion of the uplink frequency band and subcarriers for the transmission of uplink control signals are within an outer portion of the uplink frequency band.

30. A base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the base station comprising:

a transmitter configured to transmit a request for a probing signal to a mobile device in the system; and

a receiver configured to receive the probing signal from the mobile device, wherein:

the probing signal contains a code sequence modulated in the frequency domain;

the probing signal overlaps, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and

the probing signal occupies a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.

31. The base station of claim **30**, wherein the receiver is further configured to estimate, based on the received probing signal, a channel profile in the frequency domain.

32. The base station of claim **31**, further comprising using the channel profile to determine a transmission format for a subsequent transmission over the channel.

33. The base station of claim **32**, wherein the transmission format comprises a modulation/coding or pilot pattern.

34. The base station of claim **31**, further comprising using the channel profile for beamforming in a subsequent transmission to the mobile device.

35. The base station of claim **30**, wherein the portion of spectrum is available for transmission of uplink data signals by other mobile devices in the system during a time period when the portion of the spectrum is not occupied by the probing signal.

36. The base station of claim **30**, wherein the portion of spectrum is within a center portion of the uplink frequency band and subcarriers for the transmission of uplink control signals are within an outer portion of the uplink frequency band.

* * * * *

Exhibit 7

Exhibit 7
Claim 1 of U.S. Patent No. 8,467,366

U.S. Patent No. 8,467,366: Claim 1(a)

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

1. In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising:	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '366 patent. *E.g.*, The LTE specification (Series 36, Release 8) supports user equipment (UE) to perform a random access procedure. For example, release 8 of the 36 series 3GPP specifications was frozen in December of 2008 and that release was used as the basis for the first wave of LTE equipment. The LTE marketplace currently supports a mix of releases from Release 8 through Release 15. For ease of review release 8 of the LTE specification is cited below, but similar cites are available for each corresponding release on the market. The LTE network has many eNodeBs, base stations.

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U.S. Patent No. 8,467,366: Claim 1(a)

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

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4 Overall architecture

The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs.

The E-UTRAN architecture is illustrated in Figure 4 below.

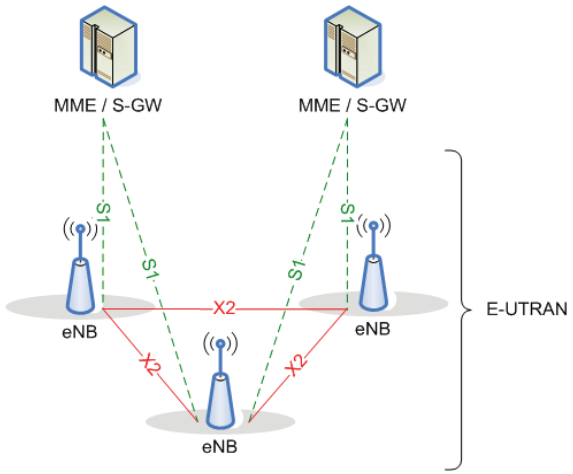


Figure 4-1: Overall Architecture

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 15.

The user equipment (UE), mobile station, communicates with a corresponding eNodeB.

U.S. Patent No. 8,467,366: Claim 1(a)

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

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4.3.1 User plane

The figure below shows the protocol stack for the user-plane, where PDCP, RLC and MAC sublayers (terminated in eNB on the network side) perform the functions listed for the user plane in subclause 6, e.g. header compression, ciphering, scheduling, ARQ and HARQ;

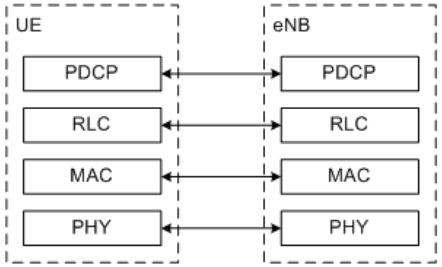


Figure 4.3.1-1: User-plane protocol stack

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 18.

LTE uses OFDMA for both the downlink and the uplink. For the uplink, LTE uses a specific type of OFDM referred to a discrete Fourier Transform Spread (DFTS)-OFDM.

5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

U.S. Patent No. 8,467,366: Claim 1(a)

"In a multi-cell orthogonal frequency division multiple access (OFDMA) wireless communication system comprising a plurality of base stations and mobile stations, a mobile station configured to communicate with a serving base station in a cell via a communication channel, the mobile station comprising: "

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5.2.1 Basic transmission scheme

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

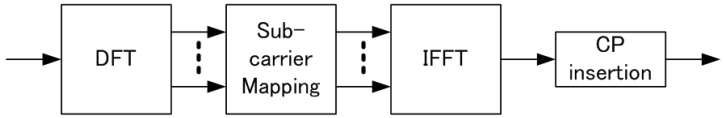


Figure 5.2.1-1: Transmitter scheme of SC-FDMA

See e.g., 3GPP TS 36.300 V8.12.0 at pgs. 27-28.

In LTE, data is transmitted using the physical uplink shared channel.

5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- transform precoding to generate complex-valued symbols
- mapping of complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

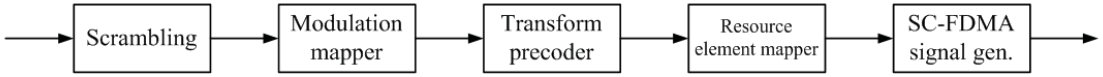
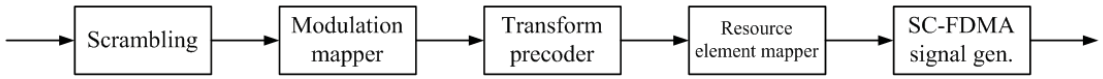


Figure 5.3-1: Overview of uplink physical channel processing.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

U.S. Patent No. 8,467,366: Claim 1(b)

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"

an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and	Honda's Accused Products each include an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel. *E.g.*, In LTE, data is transmitted using the physical uplink shared channel. 5.3 Physical uplink shared channel The baseband signal representing the physical uplink shared channel is defined in terms of the following steps: - scrambling - modulation of scrambled bits to generate complex-valued symbols - transform precoding to generate complex-valued symbols - mapping of complex-valued symbols to resource elements - generation of complex-valued time-domain SC-FDMA signal for each antenna port  **Figure 5.3-1: Overview of uplink physical channel processing.** *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 13. The LTE uplink is divided into physical resource blocks (PRBs). Each PRB has 12 adjacent subcarriers.

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U.S. Patent No. 8,467,366: Claim 1(b)

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"

5.2.3 Resource blocks

A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

The eNodeB assigns the UE a set of contiguous or adjacent PRBs using PDCCH format 0, thereby forming a data subchannel.

8.1 Resource Allocation for PDCCH DCI Format 0

The resource allocation information indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB}. A resource allocation field in the scheduling grant consists of a resource indication value (RIV) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{CRBs} \geq 1$). The resource indication value is defined by

if $(L_{CRBs} - 1) \leq \lfloor N_{RB}^{UL} / 2 \rfloor$ then

$$RIV = N_{RB}^{UL}(L_{CRBs} - 1) + RB_{START}$$

else

$$RIV = N_{RB}^{UL}(N_{RB}^{UL} - L_{CRBs} + 1) + (N_{RB}^{UL} - 1 - RB_{START})$$

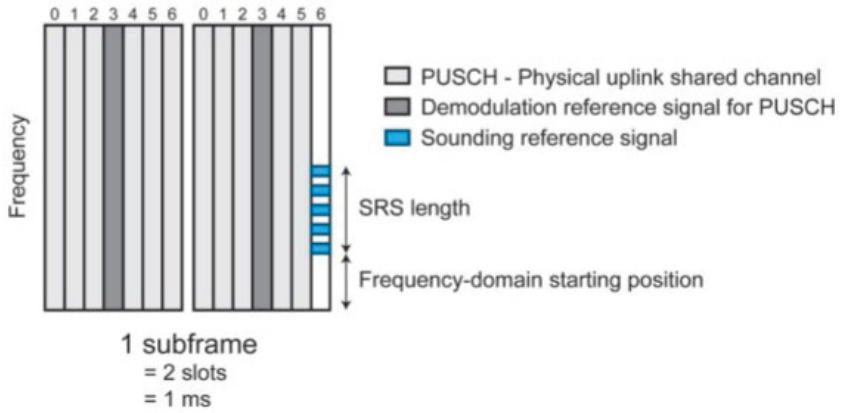
A UE shall discard PUSCH resource allocation in the corresponding PDCCH with DCI format 0 if consistent control information is not detected.

See e.g., 3GPP TS 36.213 V8.8.0 at pg. 55.

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U.S. Patent No. 8,467,366: Claim 1(b)

"an apparatus configured to transmit a data signal to the serving base station in the cell over a data subchannel, wherein the data subchannel comprises a plurality of adjacent or non-adjacent subcarriers within the communication channel; and"



See: Rumney, Moray, LTE and the Evolution to 4G Wireless § 3.2.8.3 at pg. 103.

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U.S. Patent No. 8,467,366: Claim 1(c)

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:	Honda's Accused Products each include an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access. *E.g.*, The UE transmits a preamble, ranging signal, to the eNodeB over a physical random access channel. The physical channels of E-UTRA are: **Physical random access channel (PRACH)** - Carries the random access preamble. *See e.g.*, 3GPP TS 36.300 V8.7.0 at pgs. 24 and 25. The eNodeB defines physical frequency resources, ranging subchannel, for the PRACH. The UE also receives a random access response. 6.1 Physical non-synchronized random access procedure From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission. *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 16. 5.7.1 Time and frequency structure ...

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U.S. Patent No. 8,467,366: Claim 1(c)

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

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	Table 5.7.1-4 lists the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, D_{RA}. Each quadruple of the format $(f_{RA}, t_{RA}^0, t_{RA}^1, t_{RA}^2)$ indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{RA}^0 = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{RA}^1 = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where t_{RA}^2 is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points, with the exception of preamble format 4 where t_{RA}^2 is denoted as (*). The start of the random access preamble formats 0-3 shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{TA} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_s$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{TA} = 0$. The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 35. The random access response has an uplink timing adjustment, which is adjusted based on the UE's range to the eNodeB.

U.S. Patent No. 8,467,366: Claim 1(c)

"an apparatus configured to transmit a ranging signal to the serving base station in the cell over a ranging subchannel for random access, wherein:"

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5.2 Maintenance of Uplink Time Alignment

The UE has a configurable timer *timeAlignmentTimer* which is used to control how long the UE is considered uplink time aligned [8].

The UE shall:

- when a Timing Advance Command MAC control element is received:
  - apply the Timing Advance Command;
  - start or restart *timeAlignmentTimer*.
- when a Timing Advance Command is received in a Random Access Response message:
  - if the Random Access Preamble was not selected by UE MAC:
    - apply the Timing Advance Command;
    - start or restart *timeAlignmentTimer*.
  - else, if the *timeAlignmentTimer* is not running:
    - apply the Timing Advance Command;
    - start *timeAlignmentTimer*;
    - when the contention resolution is considered not successful as described in subclause 5.1.5, stop *timeAlignmentTimer*.
  - else:
    - ignore the received Timing Advance Command.
- when *timeAlignmentTimer* expires:
  - flush all HARQ buffers;
  - notify RRC to release PUCCH/SRS;
  - clear any configured downlink assignments and uplink grants.

See e.g., 3GPP TS 36.321 V8.12.0 at pg. 17.

U.S. Patent No. 8,467,366: Claim 1(d)

"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;	The ranging signal used with Honda's Accused Products is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station. *E.g.*, The transmitted PRACH preamble is a selected Zadoff-Chu sequence. Each cell has a set of 64 sequences. 5.7.2 Preamble sequence generation The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use. There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 39. In response to the transmitted preamble, the eNodeB sends back the RA-preamble identifier, so that the UE knows its selected preamble was received by the eNodeB and the received random access response is for the UE.

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U.S. Patent No. 8,467,366: Claim 1(d)

"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

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10.1.5.1 Contention based random access procedure

The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:

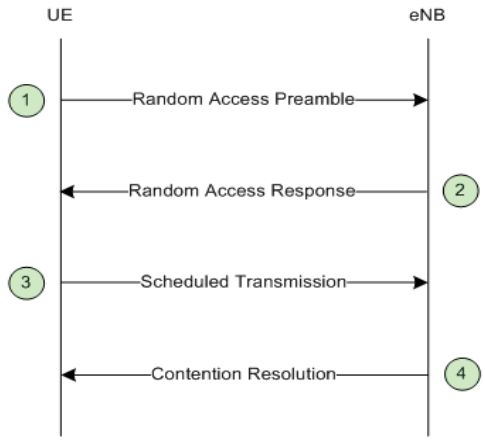


Figure 10.1.5.1-1: Contention based Random Access Procedure

The four steps of the contention based random access procedures are:

1) Random Access Preamble on RACH in uplink:
   - There are two possible groups defined and one is optional. If both groups are configured the size of message 3 and the pathloss are used to determine which group a preamble is selected from. The group to which a preamble belongs provides an indication of the size of the message 3 and the radio conditions at the UE. The preamble group information along with the necessary thresholds are broadcast on system information.
2) Random Access Response generated by MAC on DL-SCH:
   - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
   - No HARQ;
   - Addressed to RA-RNTI on PDCCH;
   - Conveys at least RA-preamble identifier, Timing Alignment information, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon Contention Resolution);
   - Intended for a variable number of UEs in one DL-SCH message.

See e.g., 3GPP TS 36.300 V8.7.0 at pgs. 52 and 53.

U.S. Patent No. 8,467,366: Claim 1(d)

"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

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10.1.5.2 Non-contention based random access procedure

The non-contention based random access procedure is outlined on Figure 10.1.5.2-1 below:

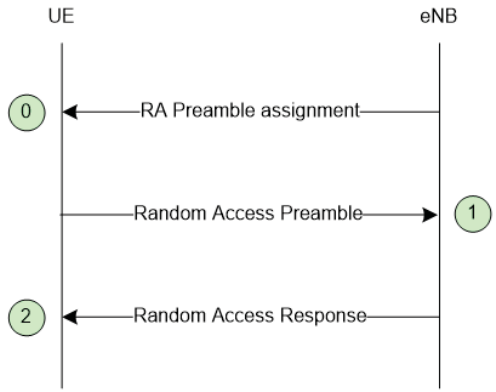


Figure 10.1.5.2-1: Non-contention based Random Access Procedure

The three steps of the non-contention based random access procedures are:

U.S. Patent No. 8,467,366: Claim 1(d)

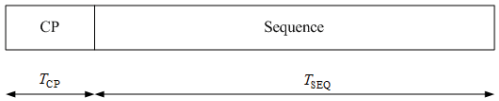
"the ranging signal is formed from a ranging sequence selected from a set of ranging sequences associated with the cell for identifying the mobile station;"

	0) Random Access Preamble assignment via dedicated signalling in DL: - eNB assigns to UE a non-contention Random Access Preamble (a Random Access Preamble not within the set broadcasted on BCH). - Signalled via: - HO command generated by target eNB and sent via source eNB for handover; - PDCCH in case of DL data arrival. 1) Random Access Preamble on RACH in uplink: - UE transmits the assigned non-contention Random Access Preamble. 2) Random Access Response on DL-SCH: - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1; - No HARQ; - Addressed to RA-RNTI on PDCCH; - Conveys at least: - Timing Alignment information and initial UL grant for handover; - Timing Alignment information for DL data arrival; - RA-preamble identifier. - Intended for one or multiple UEs in one DL-SCH message. *See e.g.*, 3GPP TS 36.300 V8.7.0 at pgs. 54 and 55.

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U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and	The ranging signal used with Honda's Accused Products lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols. *E.g.*, The PRACH preamble has a defined length, such as 3168 T_S+ 24576 T_S. 5.7.1 Time and frequency structure The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ}. The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.  **Figure 5.7.1-1: Random access preamble format.** **Table 5.7.1-1: Random access preamble parameters.** | Preamble format	T_{CP}	T_{SEQ}
---	---	---
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4*	$448 \cdot T_s$	$4096 \cdot T_s$	 *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 33. The time unit T_s is 1/(15000*2048) seconds. The preamble length is for configurations 0-3 from 0.9 to 2.28 ms.

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U.S. Patent No. 8,467,366: Claim 1(e)
"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

	4 Frame structure Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units $T_s = 1/(15000 \times 2048)$ seconds. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 9.

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U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

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11.3.1.2. Preamble Structure and Sequence Selection

The preamble consists of two parts:

- A preamble sequence
- A cyclic prefix

Furthermore, the preamble transmission uses a guard period to handle the timing uncertainty. Prior to starting the random-access procedure, the device has obtained downlink synchronization from the cell-search procedure. However, as uplink synchronization has not yet been established prior to random access, there is an uncertainty in the uplink timing[7] as the location of the device in the cell is not known. The uplink timing uncertainty is proportional to the cell size and amounts to 6.7 μs/km. To account for the timing uncertainty and to avoid interference with subsequent subframes not used for random access, a guard time is used as part of the preamble transmission—that is, the length of the actual preamble is shorter than 1 ms.

Including a cyclic prefix as part of the preamble is beneficial as it allows for frequency-domain processing at the base station (discussed later in this chapter), which can be advantageous from a complexity perspective. Preferably, the length of the cyclic prefix is approximately equal to the length of the guard period. With a preamble sequence length of approximately 0.8 ms, there is 0.1 ms cyclic prefix and 0.1 ms guard time. This allows for cell sizes up to 15 km and is the typical random-access configuration, configuration 0 in Figure 11.11. To handle larger cells, where the timing uncertainty is larger, preamble configurations 1–3 can be used. Some of these configurations also support a longer preamble sequence to increase the preamble energy at the detector, which can be beneficial in larger cells. The preamble configuration used in a cell is signaled as part of the system information. Finally, note that guard times larger than those in Figure 11.11 can easily be created by not scheduling any uplink transmissions in the subframe following the random-access resource.

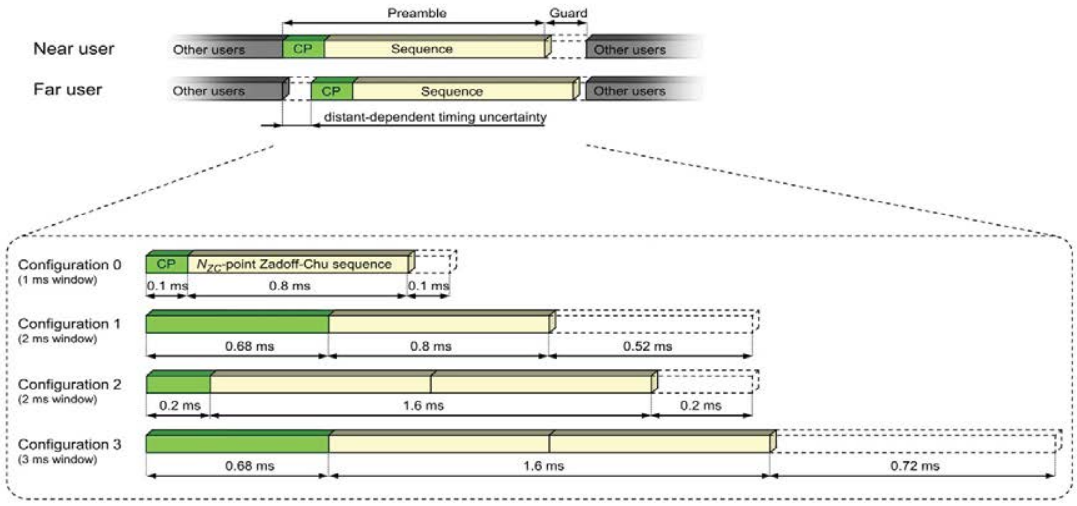


FIGURE 11.11 Different preamble formats.

See: Dahlman, Parkvall, Skold, 4G LTE-Advanced Pro and The Road to 5G, Third Edition, § 11.3.1.2.

U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

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The LTE frame has 0.5 ms slots.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10$ ms long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

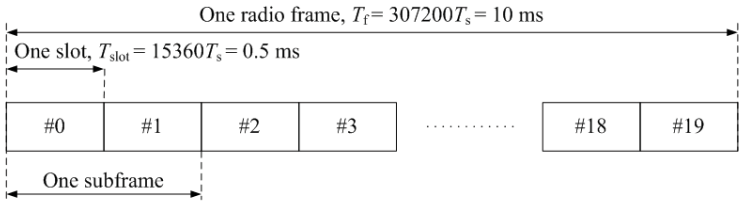


Figure 4.1-1: Frame structure type 1.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 10.

Each slot has 6 or 7 symbols, so the duration of a symbol is 0.083 ms or 0.071 ms.

U.S. Patent No. 8,467,366: Claim 1(e)

"the ranging signal lasts over a period of one or multiple orthogonal frequency division multiplexing (OFDM) symbols and"

	5.2.3 Resource blocks A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain. **Table 5.2.3-1: Resource block parameters.** | Configuration | N_{sc}^{RB} | N_{symb}^{UL} | | --- | --- | --- | | Normal cyclic prefix | 12 | 7 | | Extended cyclic prefix | 12 | 6 | *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 13.

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U.S. Patent No. 8,467,366: Claim 1(f)

"the ranging signal exhibits a low peak-to-average power ratio in the time domain; and"

the ranging signal exhibits a low peak-to-average power ratio in the time domain; and	The ranging signal used with Honda's Accused Products exhibits a low peak-to-average power ratio in the time domain. *E.g.*, The RACH preamble is generated from a Zadoff-Chu sequence. 5.7.2 Preamble sequence generation The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use. There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 39. Zadoff-Chu sequences have a low peak-to-average power ratio. **11.3.1.4. Preamble Sequence Generation** The preamble sequences are generated from cyclic shifts of root Zadoff–Chu sequences [34]. Zadoff–Chu sequences are also used for creating the uplink reference signals as described in Chapter 7, where the structure of those sequences is described. From each root Zadoff–Chu sequence $X_{ZC}^{(u)}(k)$, $\lfloor N_{ZC}/N_{CS} \rfloor$ cyclically shifted[8] sequences are obtained by cyclic shifts of N_{CS} each, where N_{ZC} is the length of the root Zadoff–Chu sequence. The generation of the random-access preamble is illustrated in Figure 11.12. Although the figure illustrates generation in the time domain, frequency-domain generation can equally well be used in an implementation. Cyclically shifted Zadoff–Chu sequences possess several attractive properties. The amplitude of the sequences is constant, which ensures efficient power amplifier utilization and maintains the low PAR properties of the single-carrier uplink. The sequences also have ideal cyclic auto-correlation, which is important for obtaining an accurate timing estimation at the eNodeB. Finally, the cross-correlation between different preambles based on cyclic shifts of the same Zadoff–Chu root sequence is zero at the receiver as long as the cyclic shift N_{CS} used when generating the preambles is larger than the maximum round-trip propagation time in the cell plus the maximum delay spread of the channel. Therefore, due to the ideal cross-correlation property, there is no intra-cell interference from multiple random-access attempts using preambles derived from the same Zadoff–Chu root sequence. *See*: Dahlman, Parkvall, Skold, 4G LTE-Advanced Pro and The Road to 5G, Third Edition, § 11.3.1.4.

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U.S. Patent No. 8,467,366: Claim 1(f)
"the ranging signal exhibits a low peak-to-average power ratio in the time domain; and"

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7.2.1 Zadoff–Chu Sequences

Zadoff–Chu (ZC) sequences (also known as Generalized Chirp-Like (GCL) sequences) are named after the papers [1] and [2]. They are non-binary unit-amplitude sequences [3], which satisfy a Constant Amplitude Zero Autocorrelation (CAZAC) property. CAZAC sequences are complex signals of the form $e^{j\alpha_k}$. The ZC sequence of odd-length N_{ZC} is given by

$$a_q(n) = \exp\left[-j2\pi q \frac{n(n+1)/2 + ln}{N_{ZC}}\right] \tag{7.1}$$

where $q \in \{1, \ldots, N_{ZC} - 1\}$ is the ZC sequence root index, $n = 0, 1, \ldots, N_{ZC} - 1$, $l \in \mathbb{N}$ is any integer. In LTE $l = 0$ is used for simplicity.

ZC sequences have the following important properties.

Property 1. A ZC sequence has constant amplitude, and its N_{ZC}-point DFT also has constant amplitude. The constant amplitude property limits the Peak-to-Average Power Ratio (PAPR) and generates bounded and time-flat interference to other users. It also simplifies the implementation as only phases need to be computed and stored, not amplitudes.

See: Sesia, Toufik, Baker, LTE, The UMTS Long Term Evolution from Theory to Practice (2009), § 7.2.1.

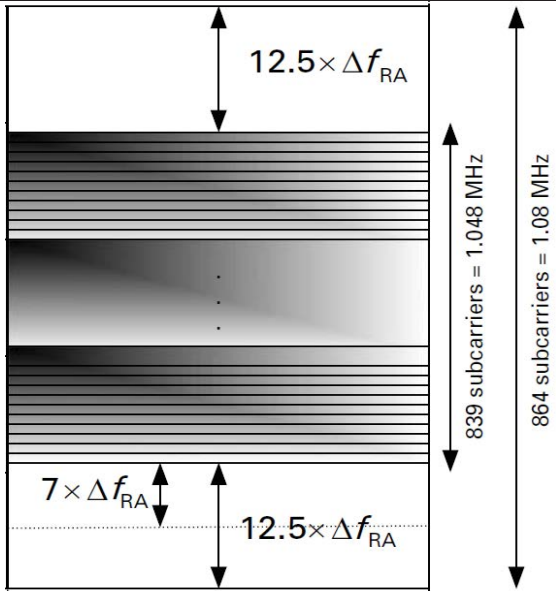
U.S. Patent No. 8,467,366: Claim 1(g)

"the ranging subchannel comprises at least one block of subcarriers within the communication channel and "

the ranging subchannel comprises at least one block of subcarriers within the communication channel and	The ranging subchannel used with Honda's Accused Products comprises at least one block of subcarriers within the communication channel. E.g., The PRACH uses 6 PRBs. **6.1 Physical non-synchronized random access procedure** From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission. *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 16. The 6 PRBs used for the PRACH are divided such as into 864 subcarriers for preamble formats 0-3. The u^{th} root Zadoff-Chu sequence is defined by $$x_u(n) = e^{-j\frac{\pi un(n+1)}{N_{ZC}}}, \quad 0 \le n \le N_{ZC} - 1$$ where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the u^{th} root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{CS} - 1$ are defined by cyclic shifts according to $$x_{u,v}(n) = x_u((n + C_v) \bmod N_{ZC})$$ ... **Table 5.7.2-1: Random access preamble sequence length.** | Preamble format	N_{ZC}
0 – 3	839
4	139 | 173

U.S. Patent No. 8,467,366: Claim 1(g)

"the ranging subchannel comprises at least one block of subcarriers within the communication channel and "



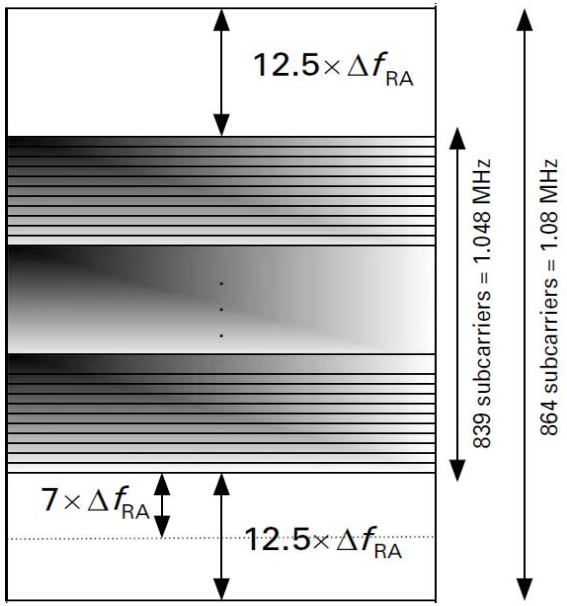
Source: Kahn, Farooq, LTE for 4G Mobile Broadband § 10.2.

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power levels of subcarriers at both ends of a block are set to zero.	The power levels of subcarriers at both ends of a block are set to zero. E.g., Out of the 864 subcarriers within the six PRBs, only 839 subcarriers are used with 12.5 subcarriers on each side are nulled. **Table 5.7.2-1: Random access preamble sequence length.** 	Preamble format	N_{ZC}
0 – 3	839
4	139 | See e.g., 3GPP TS 36.211 V8.9.0 at pg. 40. 5.7.3 Baseband signal generation The time-continuous random access signal $s(t)$ is defined by $$s(t) = \beta_{\text{PRACH}} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$ where $0 \le t < T_{SEQ} + T_{CP}$, β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power P_{PRACH} specified in Section 6.1 in [4], and $k_0 = n_{PRB}^{RA} N_{sc}^{RB} - N_{RB}^{UL} N_{sc}^{RB} / 2$. The location in the frequency domain is controlled by the parameter n_{PRB}^{RA} is derived from section 5.7.1. The factor $K = \Delta f / \Delta f_{RA}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1. **Table 5.7.3-1: Random access baseband parameters.** | Preamble format	Δf_{RA}	φ
---	---	---
0 – 3	1250 Hz	7
4	7500 Hz	2	 See e.g., 3GPP TS 36.211 V8.9.0 at pg. 43.

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Source: Kahn, Farooq, LTE for 4G Mobile Broadband § 10.2.

Exhibit 8

Exhibit 8
Claim 11 of U.S. Patent No. 10,833,908

US Patent No. 10,833,908: Claim 11(a)

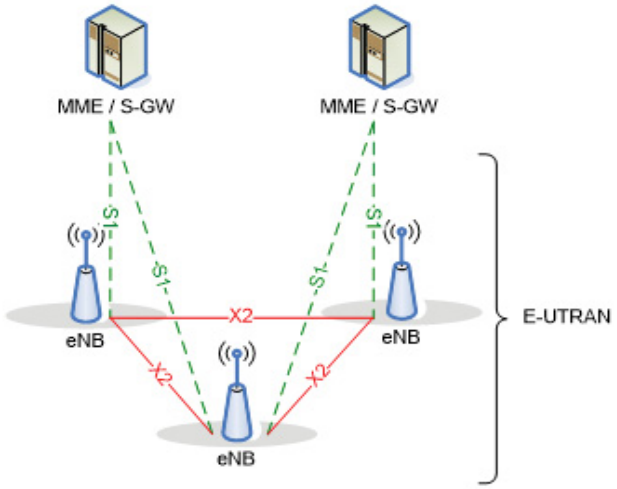
"11. A method performed by a mobile station, the method comprising:"

11. A method performed by a mobile station, the method comprising:	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '908 patent. *E.g.*, The LTE specification (Series 36, Release 8) supports user equipment (UE) to perform a random access (RACH) procedure. For example, release 8 of the 36 series 3GPP specifications was frozen in December of 2008 and that release was used as the basis for the first wave of LTE equipment. The LTE marketplace currently supports a mix of releases from Release 8 through Release 15. For ease of review release 8 of the LTE specification is cited below, but similar cites are available for each corresponding release on the market. An LTE communication system provides access to multiple users (user equipments (UEs)) through multiple cells associated with multiple eNodeBs. 4 Overall architecture The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs. The E-UTRAN architecture is illustrated in Figure 4 below.

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US Patent No. 10,833,908: Claim 11(a)

"11. A method performed by a mobile station, the method comprising:"

	 **Figure 4-1: Overall Architecture** *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 15.

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US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

transmitting, to a base station, a first uplink signal within a frequency band, wherein the first uplink signal is an orthogonal frequency division multiplexing (OFDM) signal and utilizes a frame format comprising a plurality of timeslots, each timeslot comprising a plurality of OFDM symbols;	Honda's Accused Products transmit, to a base station, a first uplink signal within a frequency band, wherein the first uplink signal is an OFDM signal and utilizes a frame format comprising a plurality of timeslots, each timeslot comprising a plurality of OFDM symbols. *E.g.*, A frequency band used for LTE communication has an associated channel bandwidth over which uplink and downlink communication is transmitted between the UEs and the eNodeBs.

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US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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5.6 Channel bandwidth

Requirements in present document are specified for the channel bandwidths listed in Table 5.6-1.

Table 5.6-1 Transmission bandwidth configuration N_{RB} in E-UTRA channel bandwidths

Channel bandwidth $BW_{Channel}$ [MHz]	1.4	3	5	10	15	20
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

Figure 5.6-1 shows the relation between the Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

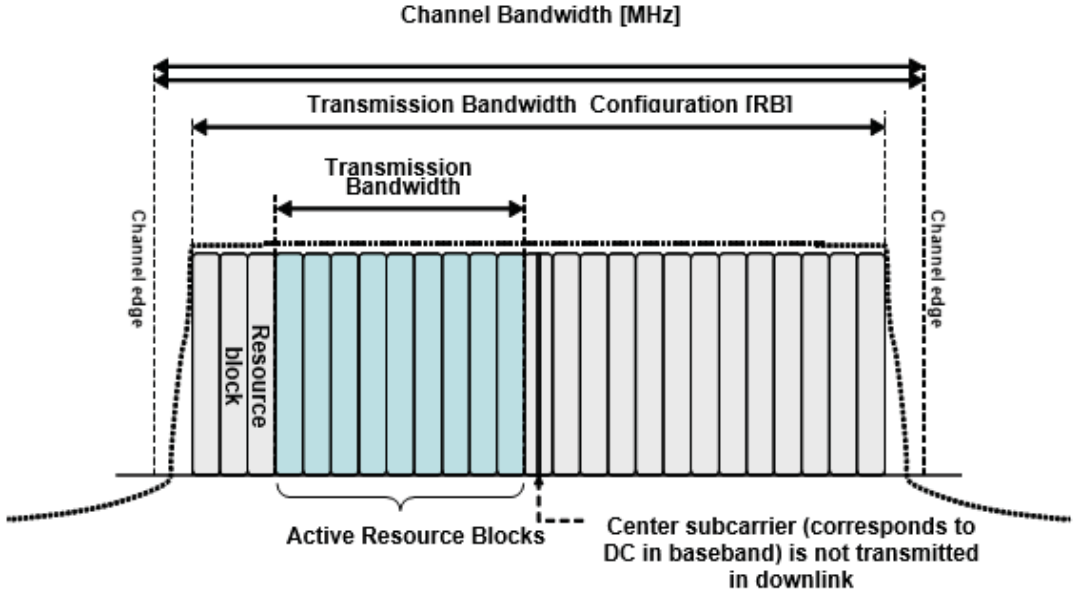


Figure 5.6-1 Definition of Channel Bandwidth and Transmission Bandwidth Configuration for one E-UTRA carrier

See e.g., 3GPP TS 36.101 V8.29.0 at pg. 15.

US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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For the uplink, LTE uses a specific type of OFDM referred to a discrete Fourier Transform Spread (DFTS)-OFDM.

5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

5.2.1 Basic transmission scheme

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

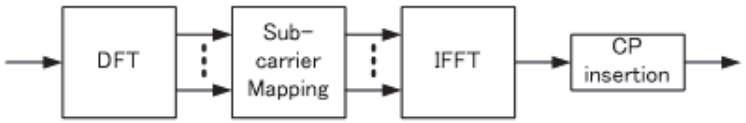


Figure 5.2.1-1: Transmitter scheme of SC-FDMA

The uplink sub-carrier spacing $\Delta f = 15$ kHz. The sub-carriers are grouped into sets of 12 consecutive sub-carriers, corresponding to the uplink resource blocks. 12 consecutive sub-carriers during one slot correspond to one uplink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

See e.g., 3GPP TS 36.300 V8.12.0 at pgs. 27-28.

The UE transmits OFDM signals carrying data on the physical uplink shared channel (PUSCH).

US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- transform precoding to generate complex-valued symbols
- mapping of complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

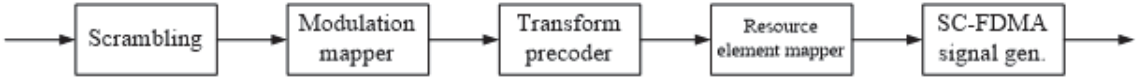


Figure 5.3-1: Overview of uplink physical channel processing.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

In LTE, both the type 1 and type 2 frame structures include multiple time slots.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10\ \text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\ \text{ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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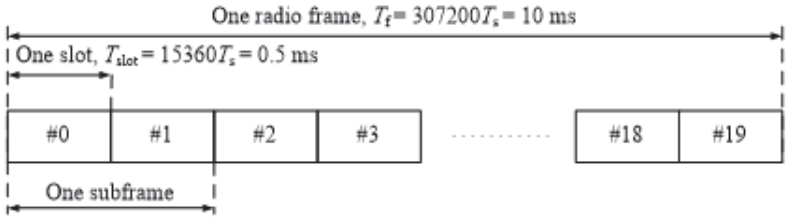


Figure 4.1-1: Frame structure type 1.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 9.

4.2 Frame structure type 2

Frame structure type 2 is applicable to TDD. Each radio frame of length $T_f = 307200 \cdot T_s = 10$ ms consists of two half-frames of length $153600 \cdot T_s = 5$ ms each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1$ ms. The supported uplink-downlink configurations are listed in Table 4.2-2 where, for each subframe in a radio frame, "D" denotes the subframe is reserved for downlink transmissions, "U" denotes the subframe is reserved for uplink transmissions and "S" denotes a special subframe with the three fields DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is given by Table 4.2-1 subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1$ ms. Each subframe i is defined as two slots, $2i$ and $2i+1$ of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms in each subframe.

Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported.

In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames.

In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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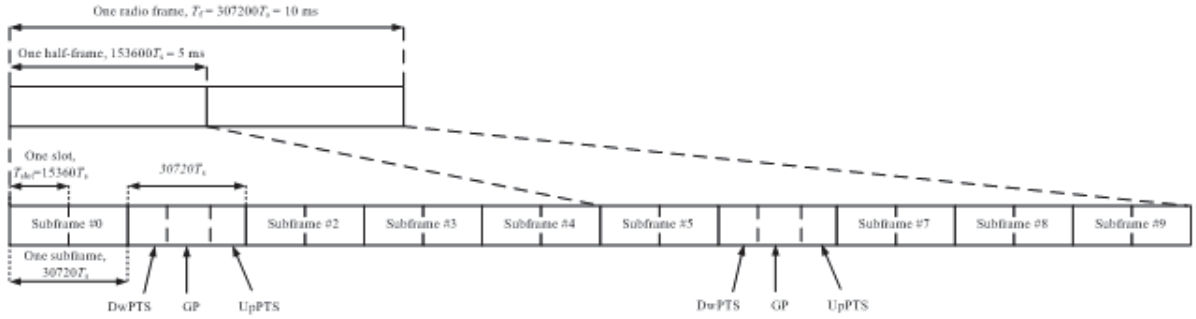


Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity).

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 10.

Each time slot includes 7 symbols for a normal cyclic prefix (6 for extended).

5.2 Slot structure and physical resources

5.2.1 Resource grid

The transmitted signal in each slot is described by a resource grid of $N_{RB}^{UL} N_{sc}^{RB}$ subcarriers and N_{symb}^{UL} SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity N_{RB}^{UL} depends on the uplink transmission bandwidth configured in the cell and shall fulfil

$$N_{RB}^{min,UL} \le N_{RB}^{UL} \le N_{RB}^{max,UL}$$

where $N_{RB}^{min,UL} = 6$ and $N_{RB}^{max,UL} = 110$ is the smallest and largest uplink bandwidth, respectively, supported by the current version of this specification. The set of allowed values for N_{RB}^{UL} is given by [7].

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is given in Table 5.2.3-1.

US Patent No. 10,833,908: Claim 11(b)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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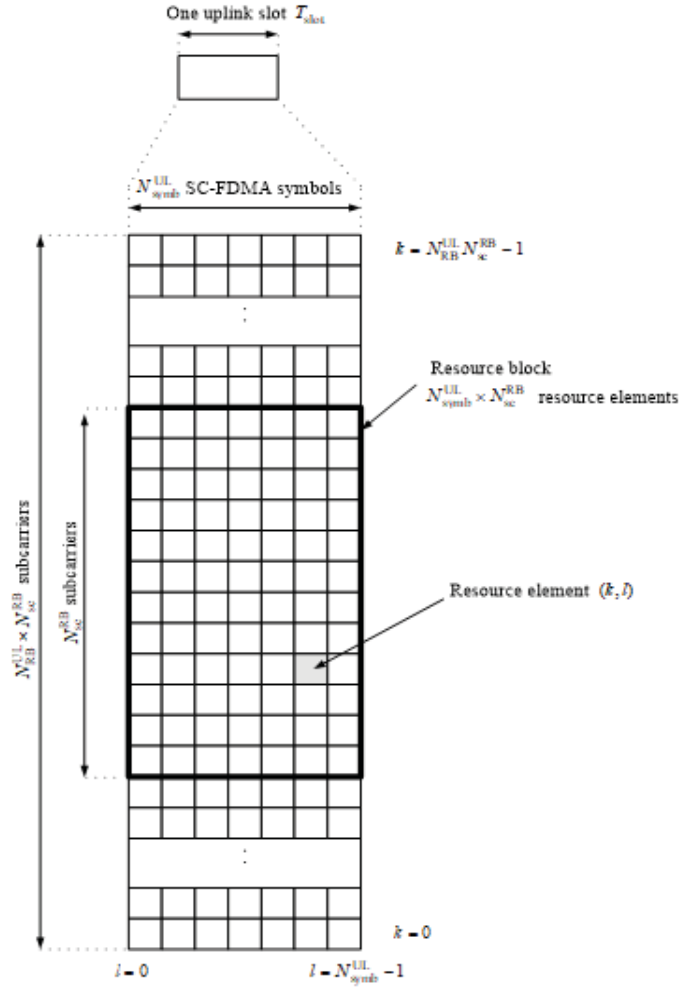


Figure 5.2.1-1: Uplink resource grid.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 12.

US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,	Honda's Accused Products transmit, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station. *E.g.*, The random access preamble transmitted on the PRACH occupies a bandwidth corresponding to 6 consecutive resource blocks in both the type 1 and type 2 frame structures, which is a fraction of the overall channel bandwidth (frequency band) for any other bandwidth than the smallest. The range of the overall channel bandwidth is the bandwidth of 6 to 100 resource blocks, corresponding to bandwidths 1.4MHz to 20MHz, with 20MHz being the most commonly used bandwidth 5.7 Physical random access channel 5.7.1 Time and frequency structure ...

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US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

	The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to $$n_{PRB}^{RA}=\begin{cases} n_{PRB_{offset}}^{RA}+6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{if } f_{RA} \bmod 2 = 0 \\ N_{RB}^{UL}-6-n_{PRB_{offset}}^{RA}-6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$ where N_{RB}^{UL} is the number of uplink resource blocks, n_{PRB}^{RA} is the first physical resource block allocated to the PRACH opportunity considered and where the parameter *prach-FrequencyOffset* $n_{PRB_{offset}}^{RA}$ is the first physical resource block available for PRACH expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{PRB_{offset}}^{RA} \le N_{RB}^{UL}-6$. For preamble format 4, the frequency multiplexing shall be done according to $$n_{PRB}^{RA}=\begin{cases} 6f_{RA}, & \text{if } \left((n_f \bmod 2)\times(2-N_{SP})+t_{RA}^{1}\right) \bmod 2 = 0 \\ N_{RB}^{UL}-6(f_{RA}+1), & \text{otherwise} \end{cases}$$ where n_f is the system frame number and where N_{SP} is the number of DL to UL switch points within the radio frame. Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pgs. 33, 35-36.

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US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

5.6 Channel bandwidth

Requirements in present document are specified for the channel bandwidths listed in Table 5.6-1.

Table 5.6-1 Transmission bandwidth configuration N_{RB} in E-UTRA channel bandwidths

Channel bandwidth $BW_{Channel}$ [MHz]	1.4	3	5	10	15	20
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

Figure 5.6-1 shows the relation between the Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

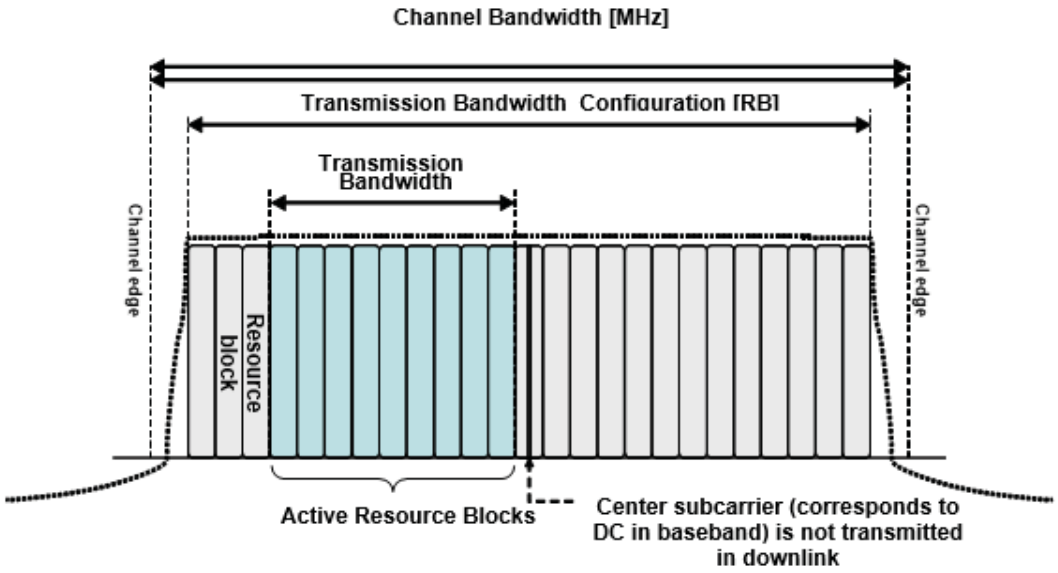


Figure 5.6-1 Definition of Channel Bandwidth and Transmission Bandwidth Configuration for one E-UTRA carrier

See e.g., 3GPP TS 36.101 V8.29.0 at pg. 15

US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

5.2.3 Resource blocks

A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

The random access burst includes a guard time added after the preamble transmission.

5.2.5 Random access preamble

The physical layer random access burst consists of a cyclic prefix, a preamble, and a guard time during which nothing is transmitted.

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, ZC-ZCZ, generated from one or several root Zadoff-Chu sequences.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 29.

17.4.2 The PRACH Structure

17.4.2.1 DFT-S-OFDM PRACH Preamble Symbol

...

US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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The UE aligns the start of the random access preamble with the start of the corresponding uplink subframe at the UE assuming a timing advance of zero (see Section 18.2), and the preamble length is shorter than the PRACH slot in order to provide room for a Guard Time (GT) to absorb the propagation delay. Figure 17.6 shows two preambles at the eNodeB received with different timings depending on the propagation delay: as for a conventional

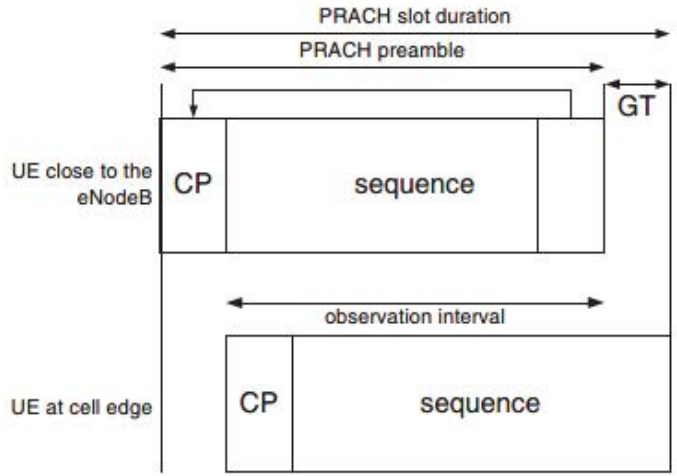


Figure 17.6: PRACH preamble received at the eNodeB.

OFDM symbol, a single observation interval can be used regardless of the UE's delay, within which periodic correlation is possible.

See Sesia, Toufik and Baker, "LTE: The UMTS Long Term Evolution From Theory to Practice", at pgs. 377-378.

US Patent No. 10,833,908: Claim 11(c)

"transmitting, to the base station, an random access signal followed by a guard period in only a portion of the frequency band, wherein the random access signal includes a sequence associated with the base station,"

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5.7.2 Preamble sequence generation

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use.

There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively.

The u^{th} root Zadoff-Chu sequence is defined by

$$x_u(n) = e^{-j\frac{\pi u n(n+1)}{N_{ZC}}}, \quad 0 \le n \le N_{ZC} - 1$$

where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the u^{th} root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{CS} - 1$ are defined by cyclic shifts according to

See e.g., 3GPP TS 36.211 V8.9.0 at p. 39.

Table 5.7.2-1: Random access preamble sequence length.

Preamble format	N_{ZC}
0 – 3	839
4	139

See e.g., 3GPP TS 36.211 V8.9.0 at p. 40.

US Patent No. 10,833,908: Claim 11(d)

"wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and"

wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and	The time duration of a combination of the random access signal and the guard period implemented using Honda's Accused Products is greater than a time duration of at least one of the plurality of OFDM symbols. *E.g.*, LTE defines a basic time unit (*T*s) and is equal to 1/ (15000 x 2048) seconds. The symbol time is 2048 **T*s or 66.7 μs. 3.1 Symbols For the purposes of the present document, the following symbols apply: ... N_{symb}^{UL} Number of SC-FDMA symbols in an uplink slot ... T_s Basic time unit *See e.g.*, 3GPP TS 36.211 V8.9.0 at pgs. 7-8. An LTE slot typically has 7 symbols, except for extended cyclic prefix which has 6 symbols. As a result, a symbol for a typical slot is ~2192 base time intervals and for extended cyclic prefix is ~2560 basic time intervals. 5.2.1 Basic transmission scheme For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM. ... There are two cyclic-prefix lengths defined: Normal cyclic prefix and extended cyclic prefix corresponding to seven and six SC-FDMA symbol per slot respectively. - Normal cyclic prefix: T_{CP} = 160×Ts (SC-FDMA symbol #0) , T_{CP} = 144×Ts (SC-FDMA symbol #1 to #6) - Extended cyclic prefix: T_{CP-e} = 512×Ts (SC-FDMA symbol #0 to SC-FDMA symbol #5) *See e.g.*, 3GPP TS 36.300 V8.12.0 at pgs. 27-28.

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US Patent No. 10,833,908: Claim 11(d)

"wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and"

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5.2 Slot structure and physical resources

5.2.1 Resource grid

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is given in Table 5.2.3-1.

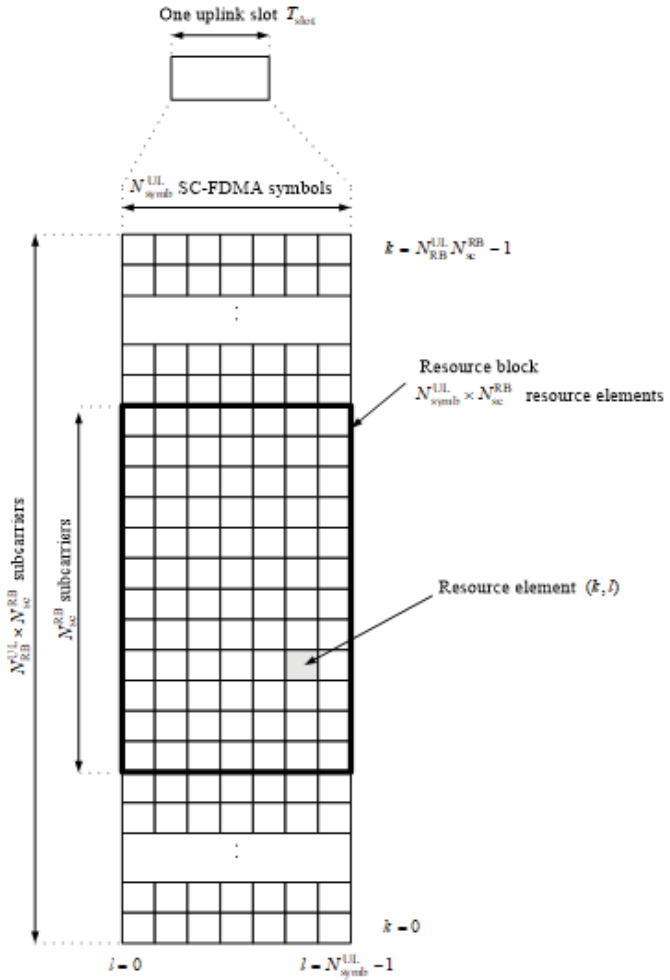


Figure 5.2.1-1: Uplink resource grid.

US Patent No. 10,833,908: Claim 11(d)

"wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and"

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 12.

5.2.3 Resource blocks

A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

Preamble formats 0-4 have sequence lengths of 4096 to 49,152 basic time intervals.

5.7 Physical random access channel

5.7.1 Time and frequency structure

The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ}. The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.

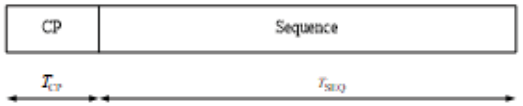


Figure 5.7.1-1: Random access preamble format.

US Patent No. 10,833,908: Claim 11(d)

"wherein a time duration of a combination of the random access signal and the guard period is greater than a time duration of at least one of the plurality of OFDM symbols; and"

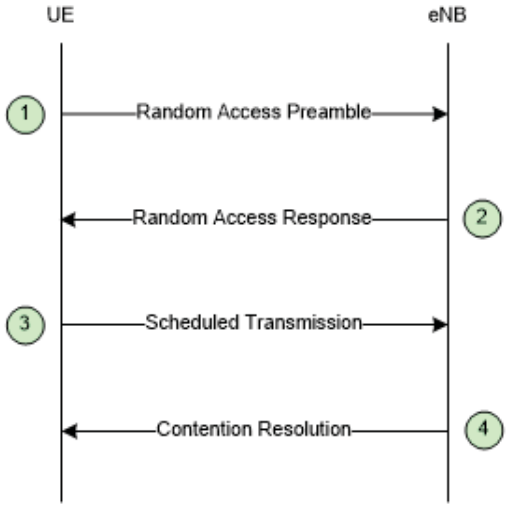
Table 5.7.1-1: Random access preamble parameters.

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4*	$448 \cdot T_s$	$4096 \cdot T_s$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 33.

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US Patent No. 10,833,908: Claim 11(e)
"receiving, from the base station, a response message."

receiving, from the base station, a response message. ;	Honda's Accused Products receive, from the base station, a response message. *E.g.*, Once the Random Access Preamble is transmitted, the UE shall monitor the PDCCH for Random Access Response(s) identified by the RA-RNTI. The random access response is sent by the eNB and received by the UE via the PDSCH and addresses with the RA-RNTI ID. 10.1.5.1 Contention based random access procedure The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:  **Figure 10.1.5.1-1: Contention based Random Access Procedure** The four steps of the contention based random access procedures are: ... 2) Random Access Response generated by MAC on DL-SCH: - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1; - No HARQ; - Addressed to RA-RNTI on PDCCH; - Conveys at least RA-preamble identifier, Timing Alignment information, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon Contention Resolution); - Intended for a variable number of UEs in one DL-SCH message.

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US Patent No. 10,833,908: Claim 11(e)
"receiving, from the base station, a response message."

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See e.g., 3GPP TS 36.300 V8.12.0 at pgs. 52-53.

10.1.5.2 Non-contention based random access procedure

The non-contention based random access procedure is outlined on Figure 10.1.5.2-1 below:

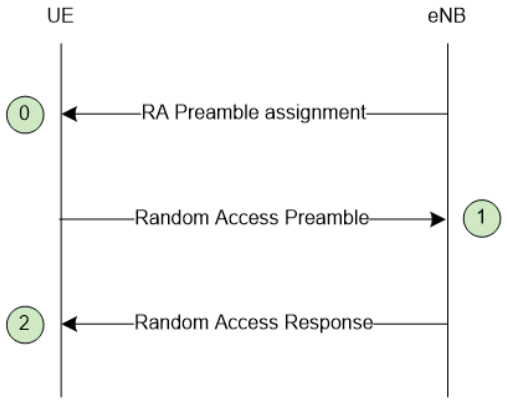


Figure 10.1.5.2-1: Non-contention based Random Access Procedure

The three steps of the non-contention based random access procedures are:

US Patent No. 10,833,908: Claim 11(e)
"receiving, from the base station, a response message."

0) Random Access Preamble assignment via dedicated signalling in DL:
   - eNB assigns to UE a non-contention Random Access Preamble (a Random Access Preamble not within the set broadcasted on BCH).
   - Signalled via:
     - HO command generated by target eNB and sent via source eNB for handover;
     - PDCCH in case of DL data arrival.
1) Random Access Preamble on RACH in uplink:
   - UE transmits the assigned non-contention Random Access Preamble.
2) Random Access Response on DL-SCH:
   - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
   - No HARQ;
   - Addressed to RA-RNTI on PDCCH;
   - Conveys at least:
     - Timing Alignment information and initial UL grant for handover;
     - Timing Alignment information for DL data arrival;
     - RA-preamble identifier.
     - Intended for one or multiple UEs in one DL-SCH message.

See e.g., 3GPP TS 36.300 V8.7.0 at pgs. 54 and 55.

5.1.4 Random Access Response reception

Once the Random Access Preamble is transmitted and regardless of the possible occurrence of a measurement gap, the UE shall monitor the PDCCH for Random Access Response(s) identified by the RA-RNTI defined below, in the RA Response window which starts at the subframe that contains the end of the preamble transmission [7] plus three subframes and has length *ra-ResponseWindowSize* subframes. The RA-RNTI associated with the PRACH in which the Random Access Preamble is transmitted, is computed as:

$$RA\text{-}RNTI = 1 + t\_id + 10 * f\_id$$

Where t_id is the index of the first subframe of the specified PRACH ($0 \leq t\_id < 10$), and f_id is the index of the specified PRACH within that subframe, in ascending order of frequency domain ($0 \leq f\_id < 6$). The UE may stop monitoring for Random Access Response(s) after successful reception of a Random Access Response containing Random Access Preamble identifiers that matches the transmitted Random Access Preamble.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 14.

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US Patent No. 10,833,908: Claim 11(e)
"receiving, from the base station, a response message."

201	**17.3.1.2 Step 2: Random Access Response** The Random Access Response (RAR) is sent by the eNodeB on the Physical Downlink Shared CHannel (PDSCH), and addressed with an ID, the Random Access Radio Network Temporary Identifier (RA-RNTI), identifying the time-frequency slot in which the preamble was detected. If multiple UEs had collided by selecting the same signature in the same preamble time-frequency resource, they would each receive the RAR. The RAR conveys the identity of the detected preamble, a timing alignment instruction to synchronize subsequent uplink transmissions from the UE, an initial uplink resource grant for transmission of the Step 3 message, and an assignment of a temporary Cell Radio Network Temporary Identifier (C-RNTI) (which may or may not be made permanent as a result of the next step – contention resolution). The RAR message can also include a 'backoff indicator' which the eNodeB can set to instruct the UE to back off for a period of time before retrying a random access attempt. *See* Sesia, Toufik and Baker, "LTE: The UMTS Long Term Evolution From Theory to Practice", at pg. 374.

Exhibit 9

Exhibit 9
Claim 13 of U.S. Patent No. 10,075,941

U.S. Patent No. 10,075,941: Claim 13(a)

"13. A mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system,"

13. A mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system,	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '941 patent. *E.g.*, The LTE specification (Series 36, Release 8) specifies user equipments (UEs) receiving downlink control information. For example, release 8 of the 36 series 3GPP specifications was frozen in December of 2008 and that release was used as the basis for the first wave of LTE equipment. The LTE marketplace currently supports a mix of releases from Release 8 through Release 15. For ease of review release 8 of the LTE specification is cited below, but similar cites are available for each corresponding release on the market. LTE uses orthogonal frequency division multiplexing (OFDM) for downlink and uplink transmissions. 4.2 General description of Layer 1 4.2.1 Multiple Access The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, two duplex modes are supported: Frequency Division Duplex (FDD), supporting full duplex and half duplex operation, and Time Division Duplex (TDD). The Layer 1 is defined in a bandwidth agnostic way based on resource blocks, allowing the LTE Layer 1 to adapt to various spectrum allocations. A resource block spans either 12 sub-carriers with a sub-carrier bandwidth of 15kHz or 24 sub-carriers with a sub-carrier bandwidth of 7.5kHz each over a slot duration of 0.5ms. *See e.g.*, 3GPP TS 36.201 V8.3.0 at pgs. 7-8. LTE downlink transmission use OFDM.

U.S. Patent No. 10,075,941: Claim 13(a)

"13. A mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system,"

	5.1 Downlink Transmission Scheme 5.1.1 Basic transmission scheme based on OFDM The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$. In addition there is also a reduced sub-carrier spacing $\Delta f_{low} = 7.5$ kHz, only for MBMS-dedicated cell. In the case of 15 kHz sub-carrier spacing there are two cyclic-prefix lengths, corresponding to seven and six OFDM symbols per slot respectively. - Normal cyclic prefix: $T_{CP} = 160 \times Ts$ (OFDM symbol #0), $T_{CP} = 144 \times Ts$ (OFDM symbol #1 to #6) *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 25 LTE uplink transmissions use discrete Fourier transform spread OFDM (DFTS-OFDM).

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"13. A mobile station served by a serving base station in an Orthogonal Frequency Division Multiplexing (OFDM) communication system,"

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5.2 Uplink Transmission Scheme

5.2.1 Basic transmission scheme

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

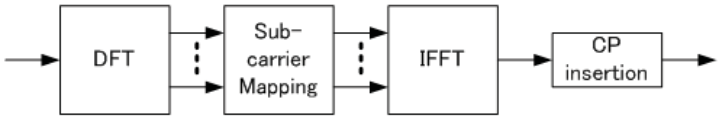


Figure 5.2.1-1: Transmitter scheme of SC-FDMA

The uplink sub-carrier spacing $\Delta f = 15$ kHz. The sub-carriers are grouped into sets of 12 consecutive sub-carriers, corresponding to the uplink resource blocks. 12 consecutive sub-carriers during one slot correspond to one uplink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

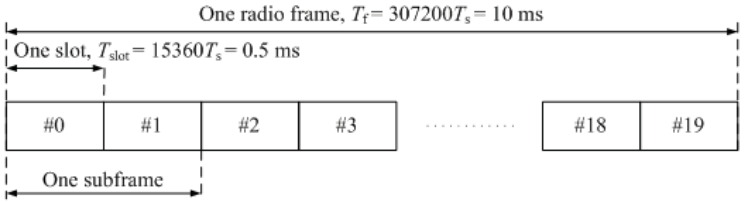
There are two cyclic-prefix lengths defined: Normal cyclic prefix and extended cyclic prefix corresponding to seven and six SC-FDMA symbol per slot respectively.

- Normal cyclic prefix: $T_{CP} = 160 \times Ts$ (SC-FDMA symbol #0), $T_{CP} = 144 \times Ts$ (SC-FDMA symbol #1 to #6)

See e.g., 3GPP TS 36.300 V8.12.0 at pgs. 27-28.

U.S. Patent No. 10,075,941: Claim 13(b)

"the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the mobile station comprising a receiver configured to:"

the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the mobile station comprising a receiver configured to:	Honda's Accused Products are served by a base station in a communication system that utilizes a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the mobile station comprising a receiver. *E.g.*, LTE networks use a frame structure having time slots, such as Frame structure type 1 for FDD. **4.1 Frame structure type 1** Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10\text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\text{ ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$. For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.  **Figure 4.1-1: Frame structure type 1.** *See e.g.*, 3GPP TS 36.211 V8.9.0 at pgs. 9-10. An LTE base station, e.g., an eNodeB assigns a set of physical resource blocks (PRBs), forming a subchannel, to a UE for downlink transmission. **11.1.1 Downlink Scheduling** In the downlink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible allocation when its downlink reception is enabled (activity governed by DRX when configured). *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 67.

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U.S. Patent No. 10,075,941: Claim 13(b)

"the communication system utilizing a transmission structure with time slots in the time domain and frequency subchannels in the frequency domain, the mobile station comprising a receiver configured to:"

Each PRB has 12 or 24 subcarriers in the frequency domain.

6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as N_{symb}^{DL} consecutive OFDM symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{DL} and N_{sc}^{RB} are given by Table 6.2.3-1. A physical resource block thus consists of $N_{symb}^{DL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to $N_{RB}^{DL} - 1$ in the frequency domain. The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

Table 6.2.3-1: Physical resource blocks parameters.

Configuration		N_{sc}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	$\Delta f = 15$ kHz	12	7
Extended cyclic prefix	$\Delta f = 15$ kHz		6
	$\Delta f = 7.5$ kHz	24	3

A virtual resource block is of the same size as a physical resource block. Two types of virtual resource blocks are defined:

- Virtual resource blocks of localized type
- Virtual resource blocks of distributed type

For each type of virtual resource blocks, a pair of virtual resource blocks over two slots in a subframe is assigned together by a single virtual resource block number, n_{VRB}.

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 46 and 47.

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U.S. Patent No. 10,075,941: Claim 13(c)

"receive a control message from the serving base station over a control channel, wherein:"

receive a control message from the serving base station over a control channel, wherein:	Honda's Accused Products receive a control message from the serving base station over a control channel. *E.g.*, The resource assignment is sent to the UE over a physical downlink control channel (PDCCH). 5 Physical Layer for E-UTRA Downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported: ... The physical channels of E-UTRA are: ... **Physical downlink control channel (PDCCH)** - Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH; - Carries the uplink scheduling grant. *See e.g.*, 3GPP TS 36.300 V8.12.0 at pgs. 23-24. The PDCCH carries downlink control information (DCI), a control message. 4.2 Downlink Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel. ... **Table 4.2-2** **Control information** / **Physical Channel** CFI / PCFICH HI / PHICH DCI / PDCCH *See e.g.*, 3GPP TS 36.212 V8.8.0 at pg. 8.

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U.S. Patent No. 10,075,941: Claim 13(c)

"receive a control message from the serving base station over a control channel, wherein:"

	5.3.3 Downlink control information A DCI transports downlink or uplink scheduling information, or uplink power control commands for one RNTI. The RNTI is implicitly encoded in the CRC. *See e.g.*, 3GPP TS 36.212 V8.8.0 at pg. 43.

U.S. Patent No. 10,075,941: Claim 13(d)

"the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and"

the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and	The control message received by Honda's Accused Products contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot. *E.g.*, The DCI includes scheduling information for a physical downlink shared channel (PDSCH) transmission. 5.3.3 Downlink control information A DCI transports downlink or uplink scheduling information, or uplink power control commands for one RNTI. The RNTI is implicitly encoded in the CRC. *See e.g.*, 3GPP TS 36.212 V8.8.0 at pg. 43. The PDSCH is transmitted in a subframe having two time slots. 7.1 UE procedure for receiving the physical downlink shared channel A UE shall upon detection of a PDCCH with DCI format 1, 1A, 1B, 1C, 1D, 2 or 2A intended for the UE in a subframe, decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers. *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 19. DCI format 2 has parameters such as a resource block assignment and precoding.

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U.S. Patent No. 10,075,941: Claim 13(d)

"the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and"

	5.3.3.1.5 Format 2 The following information is transmitted by means of the DCI format 2: - Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3] If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed. - Resource block assignment: - For resource allocation type 0 defined in section 7.1.6.1 of [3]: - $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation - For resource allocation type 1 as defined in section 7.1.6.2 of [3]: - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset - 1 bit indicates a shift of the resource allocation span - $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation where the value of P depends on the number of DL resource blocks as indicated in subclause 7.1.6.1 of [3] - TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3] - Downlink Assignment Index (this field is present in TDD for all the uplink –downlink configurations and only applies to TDD operation with uplink–downlink configuration 1-6. This field is not present in FDD) – 2 bits - HARQ process number - 3 bits (FDD), 4 bits (TDD) - Transport block to codeword swap flag – 1 bit In addition, for transport block 1: - Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3] - New data indicator – 1 bit - Redundancy version – 2 bits

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U.S. Patent No. 10,075,941: Claim 13(d)

"the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and"

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In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

Precoding information – number of bits as specified in Table 5.3.3.1.5-3

See e.g., 3GPP TS 36.212 V8.8.0 at pg. 47.

The DCI is sent in the beginning of the subframe in the control region.

6.4. Downlink L1/L2 Control Signaling

To support the transmission of downlink and uplink transport channels, there is a need for certain associated downlink control signaling. This control signaling is often referred to as downlink L1/L2 control signaling, indicating that the corresponding information partly originates from the physical layer (Layer 1) and partly from Layer 2 MAC. Downlink L1/L2 control signaling consists of downlink scheduling assignments, including information required for the device to be able to properly receive, demodulate, and decode the DL-SCH[29] on a component carrier, uplink scheduling grants informing the device about the resources and transport format to use for uplink (UL-SCH) transmission, and hybrid-ARQ acknowledgments in response to UL-SCH transmissions. In addition, the downlink control signaling can also be used for the transmission of power-control commands for power control of uplink physical channels, as well as for certain special purposes such as MBSFN notifications.

The basic time–frequency structure for transmission of L1/L2 control signaling is illustrated in Figure 6.20 with control signaling being located at the beginning of each subframe and spanning the full downlink carrier bandwidth. Each subframe can therefore be said to be divided into a control region followed by a data region, where the control region corresponds to the part of the subframe in which the L1/L2 control signaling is transmitted. Starting from release 11, there is also a possibility to locate parts of the L1/L2 control signaling in the data region as described later. However, the split of a subframe into a control region and a data region still applies.

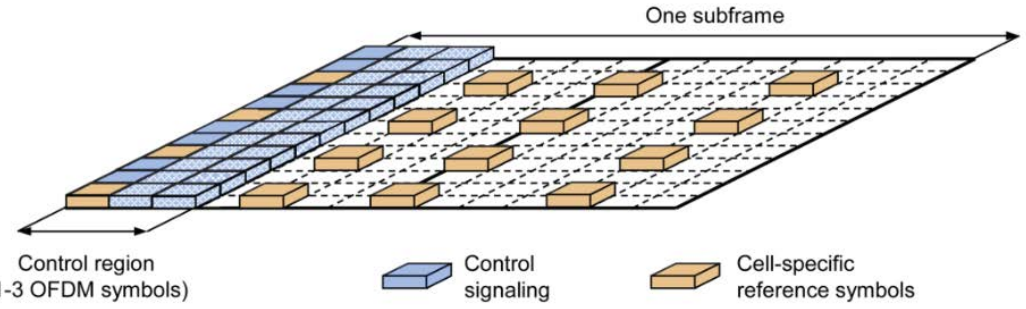


Figure 6.20 LTE time–frequency grid illustrating the split of the subframe into (variable-sized) control and data regions.

See 4G LTE-Advanced Pro and The Road to 5G, Third Edition, Dahlman et al..

U.S. Patent No. 10,075,941: Claim 13(d)

"the control message contains transmission parameters specific to the mobile station for a subsequent transmission by the serving base station over a frequency subchannel to the mobile station in a time slot; and"

	The PDSCH is sent after the control region OFDM symbols. 6.3.5 Mapping to resource elements For each of the antenna ports used for transmission of the physical channel, the block of complex-valued symbols $y^{(p)}(0),\ldots,y^{(p)}(M_{\text{symb}}^{\text{ap}}-1)$ shall be mapped in sequence starting with $y^{(p)}(0)$ to resource elements (k,l) which meet all of the following criteria: -they are in the physical resource blocks corresponding to the virtual resource blocks assigned for transmission, and -they are not used for transmission of PBCH, synchronization signals or reference signals, and -they are not in an OFDM symbol used for PDCCH as defined in section 6.7. The mapping to resource elements (k,l) on antenna port p not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks and then the index l, starting with the first slot in a subframe. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 55.

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U.S. Patent No. 10,075,941: Claim 13(e)

" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and	The mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain. *E.g.*, LTE uses multiple-input multiple-output for downlink transmissions. **5.1.5 Downlink multi-antenna transmission** Multi-antenna transmission with 2 and 4 transmit antennas is supported. The maximum number of codeword is two irrespective to the number of antennas with fixed mapping between code words to layers. Spatial division multiplexing (SDM) of multiple modulation symbol streams to a single UE using the same time-frequency (-code) resource, also referred to as Single-User MIMO (SU-MIMO) is supported. When a MIMO channel is solely assigned to a single UE, it is known as SU-MIMO. Spatial division multiplexing of modulation symbol streams to different UEs using the same time-frequency resource, also referred to as MU-MIMO, is also supported. There is semi-static switching between SU-MIMO and MU-MIMO per UE. In addition, the following techniques are supported: - Code-book-based pre-coding with a single pre-coding feedback per full system bandwidth when the system bandwidth (or subset of resource blocks) is smaller or equal to12RB and per 5 adjacent resource blocks or the full system bandwidth (or subset of resource blocks) when the system bandwidth is larger than 12RB. - Rank adaptation with single rank feedback referring to full system bandwidth. Node B can override rank report. *See e.g.*, 3GPP TS 36.300 V8.8.0 at pg. 26. DCI format 2 includes a resource block assignment, subchannel configuration, and precoding information, antenna transmission scheme. For the precoding information, an index value of 0 indicates transmission diversity, and an index, such as 2, indicates a MIMO scheme.

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U.S. Patent No. 10,075,941: Claim 13(e)

" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

216	5.3.3.1.5 Format 2 The following information is transmitted by means of the DCI format 2: - Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3] If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed. - Resource block assignment: - For resource allocation type 0 defined in section 7.1.6.1 of [3]: - $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation - For resource allocation type 1 as defined in section 7.1.6.2 of [3]: - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset - 1 bit indicates a shift of the resource allocation span - $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation where the value of P depends on the number of DL resource blocks as indicated in subclause 7.1.6.1 of [3] - TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3] - Downlink Assignment Index (this field is present in TDD for all the uplink –downlink configurations and only applies to TDD operation with uplink–downlink configuration 1-6. This field is not present in FDD) – 2 bits - HARQ process number - 3 bits (FDD), 4 bits (TDD) - Transport block to codeword swap flag – 1 bit

U.S. Patent No. 10,075,941: Claim 13(e)

" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

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In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

Precoding information – number of bits as specified in Table 5.3.3.1.5-3

...

The interpretation of the precoding information field depends on the number of enabled codewords according to Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5. Note that TPMI indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2]. For a single enabled codeword, indices 18 to 34 inclusive in Table 5.3.3.1.5-5 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with closed-loop spatial multiplexing.

...

Table 5.3.3.1.5-3: Number of bits for precoding information

Number of antenna ports at eNodeB	Number of bits for precoding information
2	3
4	6

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" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

Table 5.3.3.1.5-4: Content of precoding information field for 2 antenna ports

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	2 layers: Transmit diversity	0	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$
1	1 layer: Precoding corresponding to precoding vector $\begin{bmatrix}1 & 1\end{bmatrix}^T/\sqrt{2}$	1	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$
2	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & -1\end{bmatrix}^T/\sqrt{2}$	2	2 layers: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s)
...	...	...	...

See e.g., 3GPP TS 36.212 V8.8.0 at pgs. 49-52.

The number of enabled codewords is determined from the modulation and coding scheme and redundancy version fields for the corresponding transport block.

– In DCI formats 2 and 2A a transport block is disabled if $I_{MCS} = 0$ and if $rv_{idx} = 1$ otherwise the transport block is enabled.

See e.g., 3GPP TS 36.213 V8.8.0 at pg. 26.

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U.S. Patent No. 10,075,941: Claim 13(e)

" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

Resource allocation type 0 indicates the resource block groups assigned to the UE using a bit map. The bit map indicates whether adjacent resource block groups are used, localized subcarriers, or whether non-adjacent resource block groups are used, distributed subcarriers.

7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the resource block groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive physical resource blocks (PRBs). Resource block group size (P) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs (N_{RBG}) for downlink system bandwidth of N_{RB}^{DL} PRBs is given by $N_{RBG} = \lceil N_{RB}^{DL} / P \rceil$ where $\lfloor N_{RB}^{DL} / P \rfloor$ of the RBGs are of size P and if $N_{RB}^{DL} \bmod P > 0$ then one of the RBGs is of size $N_{RB}^{DL} - P \cdot \lfloor N_{RB}^{DL} / P \rfloor$.

The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{RBG} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

Table 7.1.6.1-1: Type 0 Resource Allocation RBG Size vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	RBG Size (P)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	4

See e.g., 3GPP TS 36.213 V8.8.0 at pgs. 22 and 23.

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U.S. Patent No. 10,075,941: Claim 13(e)

" the mobile station-specific transmission parameters indicate an antenna transmission scheme and a corresponding subchannel configuration, the antenna transmission scheme comprising a transmission diversity scheme or a multiple-input multiple-output (MIMO) scheme and the corresponding subchannel configuration characterized by distributed subcarriers or localized subcarriers in the frequency domain; and"

	7.1.6.2 Resource allocation type 1 In resource allocations of type 1, a resource block assignment information of size N_{RBG} indicates to a scheduled UE the PRBs from the set of PRBs from one of P RBG subsets. Also P is the RBG size associated with the system bandwidth as shown in Table 7.1.6.1-1. A RBG subset p, where $0 \le p < P$, consists of every P th RBG starting from RBG p. The resource block assignment information consists of three fields [4]. The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among P RBG subsets. The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise. The third field includes a bitmap, where each bit of the bitmap addresses a single PRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the PRBs in the increasing frequency order. The PRB is allocated to the UE if the corresponding bit value in the bit field is 1, the PRB is not allocated to the UE otherwise. The portion of the bitmap used to address PRBs in a selected RBG subset has size N_{RB}^{TYPE1} and is defined as $$N_{RB}^{TYPE1} = \left\lceil N_{RB}^{DL} / P \right\rceil - \lceil \log_2(P) \rceil - 1$$ *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 23.

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receive a data packet transmitted by the serving base station using the mobile station-specific transmission parameters over the frequency subchannel.	Honda's Accused Products receives a data packet transmitted by the serving base station using the mobile station-specific transmission parameters over the frequency subchannel. *E.g.*, The UE receives the downlink data over the assigned PDSCH. **7.1 UE procedure for receiving the physical downlink shared channel** A UE shall upon detection of a PDCCH with DCI format 1, 1A, 1B, 1C, 1D, 2 or 2A intended for the UE in a subframe, decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers. *See e.g.*, 3GPP TS 36.213 V8.8.0 at pg. 19. The assigned PDSCH has one or two code words, a data packet. **6.3 General structure for downlink physical channels** This section describes a general structure, applicable to more than one physical channel. The baseband signal representing a downlink physical channel is defined in terms of the following steps: - scrambling of coded bits in each of the code words to be transmitted on a physical channel - modulation of scrambled bits to generate complex-valued modulation symbols - mapping of the complex-valued modulation symbols onto one or several transmission layers - precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports - mapping of complex-valued modulation symbols for each antenna port to resource elements - generation of complex-valued time-domain OFDM signal for each antenna port

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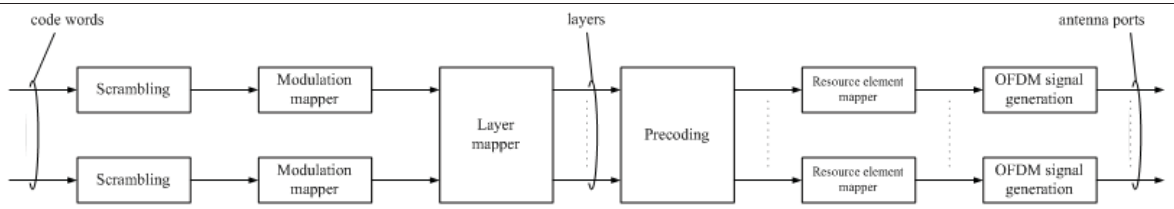


Figure 6.3-1: Overview of physical channel processing.

See e.g., 3GPP TS 36.211V8.8.0 at pgs. 49-50.

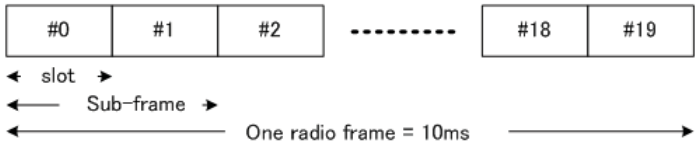
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Exhibit 10

Exhibit 10
Claim 7 of U.S. Patent No. 10,447,450

U.S. Patent No. 10,447,450: Claim 7(a)

"7. A mobile device in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the mobile device configured to"

7. A mobile device in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the mobile device configured to:	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '450 patent. *E.g.*, A release 8 compliant Long Term Evolution (LTE) user equipment (UE) uses a frame structure that is 10 ms long with ten subframes, time intervals, of 1 ms long each. Each subframe includes two slots. **5 Physical Layer for E-UTRA** Downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported: - Type 1, applicable to FDD, - Type 2, applicable to TDD. Frame structure Type 1 is illustrated in Figure 5.1-1. Each 10 ms radio frame is divided into ten equally sized sub-frames. Each sub-frame consists of two equally sized slots. For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain.  **Figure 5.1-1: Frame structure type 1** Frame structure Type 2 is illustrated in Figure 5.1-2. Each 10 ms radio frame consists of two half-frames of 5 ms each. Each half-frame consists of eight slots of length 0.5 ms and three special fields: DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is configurable subject to the total length of DwPTS, GP and UpPTS being equal to 1ms. Both 5ms and 10ms switch-point periodicity are supported. Subframe 1 in all configurations and subframe 6 in configuration with 5ms switch-point periodicity consist of DwPTS, GP and UpPTS. Subframe 6 in configuration with 10ms switch-point periodicity consists of DwPTS only. All other subframes consist of two equally sized slots. For TDD, GP is reserved for downlink to uplink transition. Other Subframes/Fields are assigned for either downlink or uplink transmission. Uplink and downlink transmissions are separated in the time domain.

U.S. Patent No. 10,447,450: Claim 7(a)

"7. A mobile device in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the mobile device configured to"

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 23.

The LTE downlink uses orthogonal frequency division multiplexing (OFDM). During a subframe, multiple OFDM symbols are transmitted.

5.1 Downlink Transmission Scheme

5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

In addition there is also a reduced sub-carrier spacing $\Delta f_{low} = 7.5$ kHz, only for MBMS-dedicated cell.

In the case of 15 kHz sub-carrier spacing there are two cyclic-prefix lengths, corresponding to seven and six OFDM symbols per slot respectively.

- Normal cyclic prefix: $T_{CP} = 160 \times Ts$ (OFDM symbol #0), $T_{CP} = 144 \times Ts$ (OFDM symbol #1 to #6)

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

A subframe contains two slots, and in each slot multiple OFDM symbols are transmitted. Each symbol includes a plurality of subcarriers.

6.2 Slot structure and physical resource elements

6.2.1 Resource grid

The transmitted signal in each slot is described by a resource grid of $N_{RB}^{DL} N_{sc}^{RB}$ subcarriers and N_{symb}^{DL} OFDM symbols.

The resource grid structure is illustrated in Figure 6.2.2-1. The quantity N_{RB}^{DL} depends on the downlink transmission bandwidth configured in the cell and shall fulfil

$$N_{RB}^{min,DL} \le N_{RB}^{DL} \le N_{RB}^{max,DL}$$

where $N_{RB}^{min,DL} = 6$ and $N_{RB}^{max,DL} = 110$ are the smallest and largest downlink bandwidth, respectively, supported by the current version of this specification.

U.S. Patent No. 10,447,450: Claim 7(a)

"7. A mobile device in a wireless packet system using a frame structure of multiple frames for transmission, each frame comprising a plurality of time intervals, each time interval comprising a plurality of orthogonal frequency division multiplexing (OFDM) symbols, and each OFDM symbol containing a plurality of frequency subcarriers, the mobile device configured to"

	See e.g., 3GPP TS 36.211 V8.9.0 at pg. 45.

U.S. Patent No. 10,447,450: Claim 7(b)

"receive an identifier from a base station in a cell in which the mobile device is operating; and"

receive an identifier from a base station in a cell in which the mobile device is operating; and	Honda's Accused Products receive an identifier from a base station in a cell in which the mobile device is operating. *E.g.*, The UE receives a cell radio network temporary identifier (C-RNTI) from an eNodeB, LTE base station.

10.1.5.1 Contention based random access procedure

The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:

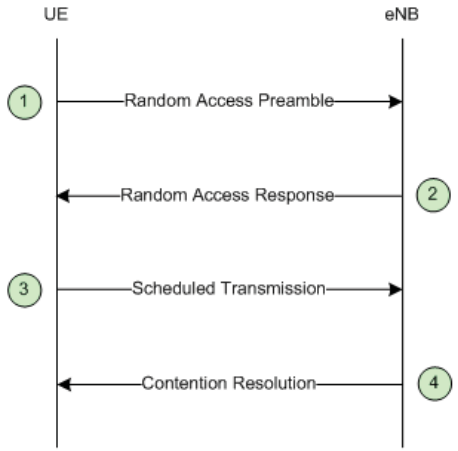


Figure 10.1.5.1-1: Contention based Random Access Procedure

The four steps of the contention based random access procedures are:

1) Random Access Preamble on RACH in uplink:
   ...
2) Random Access Response generated by MAC on DL-SCH:
   ...
   - Conveys at least RA-preamble identifier, Timing Alignment information, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon Contention Resolution);
   ...
3) First scheduled UL transmission on UL-SCH:
   ...
4) Contention Resolution on DL:
   ...
   - Addressed to:
     - The Temporary C-RNTI on PDCCH for initial access and after radio link failure;
     - The C-RNTI on PDCCH for UE in RRC_CONNECTED;
   ...

The Temporary C-RNTI is promoted to C-RNTI for a UE which detects RA success and does not already have a C-RNTI; it is dropped by others. A UE which detects RA success and already has a C-RNTI, resumes using its C-RNTI.

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U.S. Patent No. 10,447,450: Claim 7(b)

"receive an identifier from a base station in a cell in which the mobile device is operating; and"

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 52-53.

10.1.5.2 Non-contention based random access procedure

The non-contention based random access procedure is outlined on Figure 10.1.5.2-1 below:

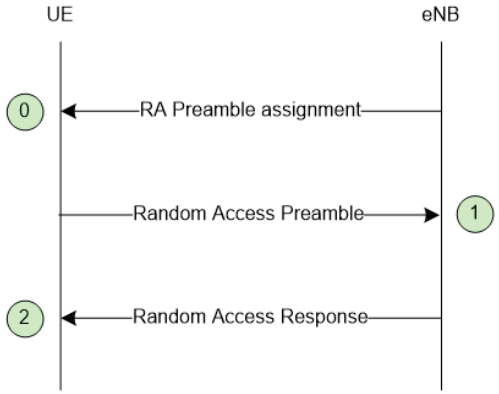


Figure 10.1.5.2-1: Non-contention based Random Access Procedure

The three steps of the non-contention based random access procedures are:

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U.S. Patent No. 10,447,450: Claim 7(b)

"receive an identifier from a base station in a cell in which the mobile device is operating; and"

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0) Random Access Preamble assignment via dedicated signalling in DL:

- eNB assigns to UE a non-contention Random Access Preamble (a Random Access Preamble not within the set broadcasted on BCH).
- Signalled via:
  - HO command generated by target eNB and sent via source eNB for handover;
  - PDCCH in case of DL data arrival.

1) Random Access Preamble on RACH in uplink:

- UE transmits the assigned non-contention Random Access Preamble.

2) Random Access Response on DL-SCH:

- Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
- No HARQ;
- Addressed to RA-RNTI on PDCCH;
- Conveys at least:
  - Timing Alignment information and initial UL grant for handover;
  - Timing Alignment information for DL data arrival;
  - RA-preamble identifier.
  - Intended for one or multiple UEs in one DL-SCH message.

See e.g., 3GPP TS 36.300 V8.7.0 at pgs. 54 and 55.

The C-RNTI is an identifier used to identify the UE at the cell level.

8.1 E-UTRAN related UE identities

The following E-UTRAN related UE identities are used at cell level:

- C-RNTI: unique identification used for identifying RRC Connection and scheduling;

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 39.

U.S. Patent No. 10,447,450: Claim 7(c)

"receive a signal containing information from the base station over a segment of time-frequency resource,"

receive a signal containing information from the base station over a segment of time-frequency resource,	Honda's Accused Products receive a signal containing information from the base station over a segment of time-frequency resource. *E.g.*, Resource information is sent from the base station to the UE over a physical downlink control channel (PDCCH). ... The physical channels of E-UTRA are: ... **Physical downlink control channel (PDCCH)** - Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH; - Carries the uplink scheduling grant. *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 24. The PDCCH carries downlink control information (DCI), a control message. 4.2 Downlink Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel. ... **Table 4.2-2** **Control information** / **Physical Channel** CFI / PCFICH HI / PHICH DCI / PDCCH *See e.g.*, 3GPP TS 36.212 V8.8.0 at pg. 8. 5.3.3 Downlink control information A DCI transports downlink or uplink scheduling information, or uplink power control commands for one RNTI. The RNTI is implicitly encoded in the CRC.

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U.S. Patent No. 10,447,450: Claim 7(c)

"receive a signal containing information from the base station over a segment of time-frequency resource,"

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See e.g., 3GPP TS 36.212 V8.8.0 at pg. 43.

The PDCCH is received over the first n OFDM symbols, wherein $n \leq 4$. A PDCCH is formed by an aggregation of control channel elements (CCEs). Each CCE consists of a set of resource elements.

5.1.3 Physical downlink control channel

The downlink control signalling (PDCCH) is located in the first n OFDM symbols where $n \leq 4$ and consists of:

- Transport format and resource allocation related to DL-SCH and PCH, and hybrid ARQ information related to DL-SCH;
- Transport format, resource allocation, and hybrid-ARQ information related to UL-SCH;

Transmission of control signalling from these groups is mutually independent.

Multiple physical downlink control channels are supported and a UE monitors a set of control channels.

Control channels are formed by aggregation of control channel elements, each control channel element consisting of a set of resource elements. Different code rates for the control channels are realized by aggregating different numbers of control channel elements.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 26.

Resource elements make up a resource grid that defines a resource block that is transmitted during a slot, each resource element being uniquely identifiable by an index pair (k, l).

6.2.2 Resource elements

Each element in the resource grid for antenna port p is called a resource element and is uniquely identified by the index pair (k,l) in a slot where $k = 0,\ldots, N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}} - 1$ and $l = 0,\ldots, N_{\mathrm{symb}}^{\mathrm{DL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.

U.S. Patent No. 10,447,450: Claim 7(c)

"receive a signal containing information from the base station over a segment of time-frequency resource,"

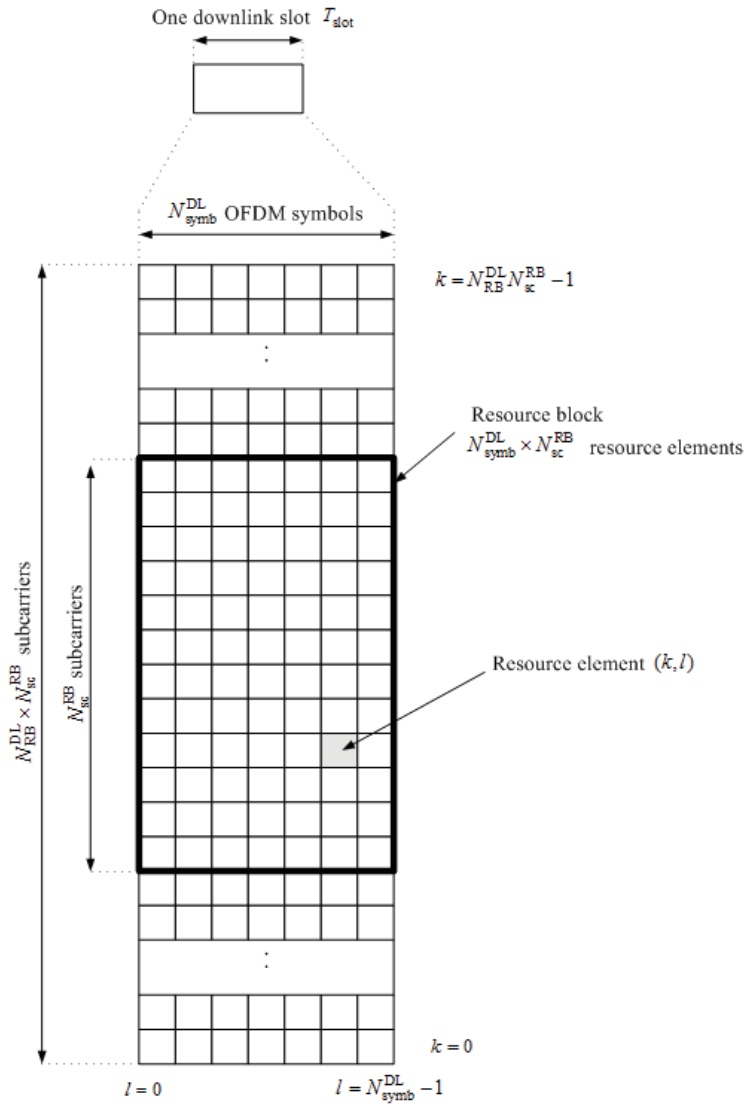


Figure 6.2.2-1: Downlink resource grid.

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 45-46.

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U.S. Patent No. 10,447,450: Claim 7(c)

"receive a signal containing information from the base station over a segment of time-frequency resource,"

Resource-element groups are used for defining the mapping of the PDCCH to resource elements.

6.2.4 Resource-element groups

Resource-element groups are used for defining the mapping of control channels to resource elements.

A resource-element group is represented by the index pair (k',l') of the resource element with the lowest index k in the group with all resource elements in the group having the same value of l. The set of resource elements (k,l) in a resource-element group depends on the number of cell-specific reference signals configured as described below with $k_0 = n_{\mathrm{PRB}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}}$, $0 \le n_{\mathrm{PRB}} < N_{\mathrm{RB}}^{\mathrm{DL}}$.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 48.

A PDCCH is an aggregation of CCEs. Each CCE corresponds to 9 resource element groups that map the PDCCH to resource element that define a segment of time-frequency resource.

6.8 Physical downlink control channel

6.8.1 PDCCH formats

The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 and $N_{CCE}-1$, where $N_{CCE} = \lfloor N_{REG}/9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number.

Multiple PDCCHs can be transmitted in a subframe.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 58.

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U.S. Patent No. 10,447,450: Claim 7(d)
"the segment having a starting time-frequency coordinate"

the segment having a starting time-frequency coordinate	The segment over which the signal containing information from the base station is received by Honda's Accused Products has a starting time-frequency coordinate. *E.g.*, The PDCCH has a starting time-frequency coordinate. It starts at a CCE fulfilling *i* mod *n* = 0, where *i* is the CCE number. The CCE corresponds to resource element groups which map CCEs to resource elements, which are uniquely identified by a time-frequency index pair. **6.8 Physical downlink control channel** **6.8.1 PDCCH formats** The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 and $N_{CCE}-1$, where $N_{CCE}=\lfloor N_{REG}/9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number. Multiple PDCCHs can be transmitted in a subframe. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 58. **6.2.4 Resource-element groups** Resource-element groups are used for defining the mapping of control channels to resource elements. A resource-element group is represented by the index pair (k',l') of the resource element with the lowest index k in the group with all resource elements in the group having the same value of l. The set of resource elements (k,l) in a resource-element group depends on the number of cell-specific reference signals configured as described below with $k_0 = n_{PRB} \cdot N_{sc}^{RB}$, $0 \le n_{PRB} < N_{RB}^{DL}$. *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 48. The PDCCH is located in the first *n* OFDM symbols, starting at the first symbol.

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U.S. Patent No. 10,447,450: Claim 7(d)
"the segment having a starting time-frequency coordinate"

	5.1.3 Physical downlink control channel The downlink control signalling (PDCCH) is located in the first n OFDM symbols where $n \leq 4$ and consists of: *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 26.

U.S. Patent No. 10,447,450: Claim 7(e)

"the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and"

the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and	The segment over which the signal containing information from the base station is received by Honda's Accused Products comprises N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8. *E.g.*, The PDCCH comprises 2 CCEs for a PDCCH format 1, 4 CCEs for a PDCCH format 2, and 8 CCEs for a PDCCH format 3. The PDCCH comprises 2, 4, or 8 CCEs depending on the aggregation level. **6.8 Physical downlink control channel** **6.8.1 PDCCH formats** The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 and $N_{CCE}-1$, where $N_{CCE}=\lfloor N_{REG}/9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number. Multiple PDCCHs can be transmitted in a subframe. **Table 6.8.1-1: Supported PDCCH formats** PDCCH format / Number of CCEs / Number of resource-element groups / Number of PDCCH bits 0 / 1 / 9 / 72 1 / 2 / 18 / 144 2 / 4 / 36 / 288 3 / 8 / 72 / 576 *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 58. Each CCE is a set of 36 resource elements, which are a set of frequency subcarriers in a group of OFDM symbols.

U.S. Patent No. 10,447,450: Claim 7(e)

"the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and"

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To allow for simple yet efficient processing of the control channels in the device, the mapping of PDCCHs to resource elements is subject to a certain structure. This structure is based on so-called *control-channel elements* (CCEs), which in essence is a convenient name for a set of 36 useful resource elements (nine resource-element groups as defined in Section 6.4.1). The number of CCEs, one, two, four, or eight, required for a certain PDCCH depends on the payload size of the control information (DCI payload) and the channel-coding rate. This is used to realize link adaptation for the PDCCH; if the channel conditions for the device to which the PDCCH is intended are disadvantageous, a larger number of CCEs needs to be used compared to the case of advantageous channel conditions. The number of CCEs used for a PDCCH is also referred to as the aggregation level.

The number of CCEs available for PDCCHs depends on the size of the control region, the cell bandwidth, the number of downlink antenna ports, and the amount of resources occupied by PHICH. The size of the control region can vary dynamically from subframe to subframe as indicated by the PCFICH, whereas the other quantities are semi-statically configured. The CCEs available for PDCCH transmission can be numbered from zero and upward, as illustrated in Figure 6.26. A specific PDCCH can thus be identified by the numbers of the corresponding CCEs in the control region.

As the number of CCEs for each of the PDCCHs may vary and is not signaled, the device has to blindly determine the number of CCEs used for the PDCCH it is addressed upon. To reduce the complexity of this process somewhat, certain restrictions on the aggregation of contiguous CCEs have been specified. For example, an aggregation of eight CCEs can only start on CCE numbers evenly divisible by 8, as illustrated in Figure 6.26. The same principle

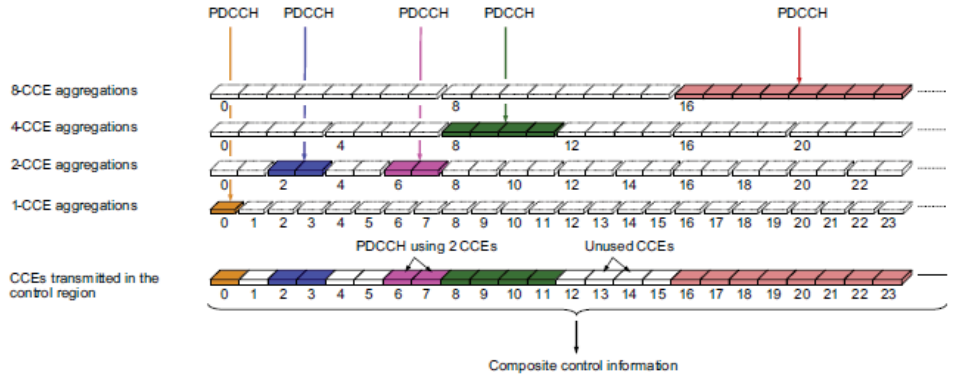


FIGURE 6.26

CCE aggregation and PDCCH multiplexing.

is applied to the other aggregation levels. Furthermore, some combinations of DCI formats and CCE aggregations that result in excessively high channel-coding rates are not supported.

U.S. Patent No. 10,447,450: Claim 7(e)

"the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and"

See e.g., 4G LTE-Advanced Pro and The Road to 5G, Third Edition, Dahlman et al.. at pgs. 141-142.

The PDCCH is received during the control region of a subframe which is the initial time interval of the subframe. The number of OFDM symbols constituting this region, or the duration of the time interval, is signalled on the Physical Control Format Indicator Channel (PCFICH). The time interval of the control region can be 1-4 OFDM symbols in length, but typically is 1-3 OFDM symbols in length.

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

Table 6.7-1: Number of OFDM symbols used for PDCCH.

Subframe	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} > 10$	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} \leq 10$
Subframe 1 and 6 for frame structure type 2	1, 2	2
MBSFN subframes on a carrier supporting both PMCH and PDSCH for 1 or 2 cell specificc antenna ports	1, 2	2
MBSFN subframes on a carrier supporting both PMCH and PDSCH for 4 cell specific antenna ports	2	2
MBSFN subframes on a carrier not supporting PDSCH	0	0
All other cases	1, 2, 3	2, 3, 4

The PCFICH shall be transmitted when the number of OFDM symbols for PDCCH is greater than zero.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 58.

U.S. Patent No. 10,447,450: Claim 7(e)

"the segment comprising N time-frequency resource units within a time interval, each unit containing a set of frequency subcarriers in a group of OFDM symbols, where N=2, 4, or 8; and"

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The basic time–frequency structure for transmission of L1/L2 control signaling is illustrated in Figure 6.20 with control signaling being located at the beginning of each subframe and spanning the full downlink carrier bandwidth. Each subframe can therefore be said to be divided into a control region followed by a data region, where the control region corresponds to the part of the subframe in which the L1/L2 control signaling is transmitted. Starting from release 11, there is also a possibility to locate parts of the L1/L2 control signaling in the data region as described later. However, the split of a subframe into a control region and a data region still applies.

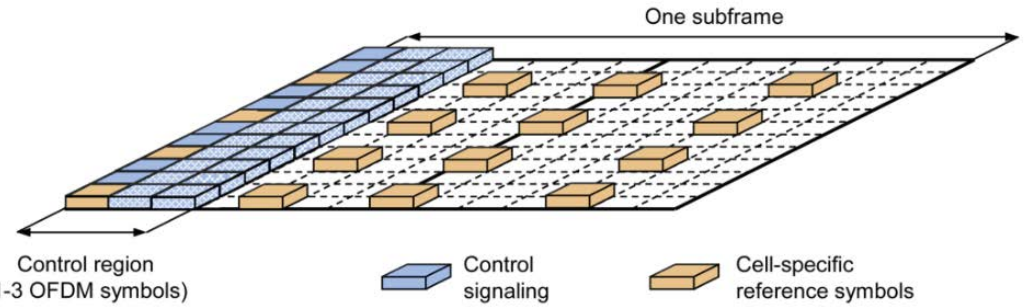


Figure 6.20 LTE time–frequency grid illustrating the split of the subframe into (variable-sized) control and data regions.

To simplify the overall design, the control region always occupies an integer number of OFDM symbols, more specifically one, two, or three OFDM symbols (for narrow cell bandwidths, 10 resource blocks or less, the control region consists of two, three, or four OFDM symbols to allow for a sufficient amount of control signaling).

The size of the control region expressed in number of OFDM symbols, or, equivalently, the start of the data region, can be dynamically varied on a per-subframe basis. Thus, the amount of radio resources used for control signaling can be dynamically adjusted to match the instantaneous traffic situation. For a small number of users being scheduled in a subframe, the required amount of control signaling is small and a larger part of the subframe can be used for data transmission (larger data region).

The maximum size of the control region is normally three OFDM symbols (four in the case of narrow cell bandwidths), as mentioned in the preceding paragraphs. However, there are a few exceptions to this rule. When operating in TDD mode, the control region in subframes one and six is restricted to at most two OFDM symbols since, for TDD, the primary synchronization signal (see Chapter 11) occupies the third OFDM symbol in those subframes. Similarly, for MBSFN subframes (see Chapter 5), the control region is restricted to a maximum of two OFDM symbols.

See e.g., 4G LTE-Advanced Pro and The Road to 5G, Third Edition, Dahlman et al.. Section 6.4 Downlink L1/L2 Control Signaling.

U.S. Patent No. 10,447,450: Claim 7(f)

"recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier."

recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier.	Honda's Accused Products also recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier. *E.g.*, The PDCCH is recovered by the UE using the first OFDM symbol of the first *n* OFDM symbols and subcarriers corresponding to the resource elements mapped to the CCEs of the PDCCH. The UE uses N, the number of CCEs, to receive the full PDCCH in the supported PDCCH format. 5.1.3 Physical downlink control channel The downlink control signalling (PDCCH) is located in the first n OFDM symbols where $n \leq 4$ and consists of: *See e.g.*, 3GPP TS 36.300 V8.12.0 at pg. 26. 6.8 Physical downlink control channel 6.8.1 PDCCH formats The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 and $N_{CCE}-1$, where $N_{CCE} = \lfloor N_{REG} / 9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number. Multiple PDCCHs can be transmitted in a subframe. **Table 6.8.1-1: Supported PDCCH formats** | PDCCH format	Number of CCEs	Number of resource-element groups	Number of PDCCH bits
---	---	---	---
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576	 *See e.g.*, 3GPP TS 36.211 V8.9.0 at pg. 58. The UE also uses the RNTI to recover the PDCCH.

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U.S. Patent No. 10,447,450: Claim 7(f)

"recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier."

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9.1.1 PDCCH Assignment Procedure

The control region consists of a set of CCEs, numbered from 0 to $N_{CCE,k}-1$ according to Section 6.8.2 in [3], where $N_{CCE,k}$ is the total number of CCEs in the control region of subframe k. The UE shall monitor a set of PDCCH candidates for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1,2,4,8\}$ is defined by a set of PDCCH candidates. The CCEs corresponding to PDCCH candidate m of the search space $S_k^{(L)}$ are given by

$$L \cdot \left\{ \left(Y_k + m \right) \bmod \left\lfloor N_{CCE,k} / L \right\rfloor \right\} + i$$

where Y_k is defined below, $i = 0, \cdots, L-1$ and $m = 0, \cdots, M^{(L)}-1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

The UE shall monitor one common search space at each of the aggregation levels 4 and 8 and one UE-specific search space at each of the aggregation levels 1, 2, 4, 8. The common and UE-specific search spaces may overlap.

The aggregation levels defining the search spaces are listed in Table 9.1.1-1. The DCI formats that the UE shall monitor depend on the configured transmission mode as defined in Section 7.1.

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"recover the information from the received signal using the starting time-frequency coordinate and N in conjunction with the received identifier."

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Table 9.1.1-1: PDCCH candidates monitored by a UE.

Type	Search space $S_k^{(L)}$ Aggregation level L	Size [in CCEs]	Number of PDCCH candidates $M^{(L)}$
UE-specific	1	6	6
	2	12	6
	4	8	2
	8	16	2
Common	4	16	4
	8	16	2

For the common search spaces, Y_k is set to 0 for the two aggregation levels $L=4$ and $L=8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level L, the variable Y_k is defined by

$$Y_k = (A \cdot Y_{k-1}) \bmod D$$

where $Y_{-1} = n_{RNTI} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame.. The RNTI value used for n_{RNTI} is defined in section 7.1 in downlink and section 8 in uplink.

See e.g., 3GPP TS 36.213 V8.8.0 at pgs. 63-64.

Exhibit 11

Exhibit 11
Claim 15 of U.S. Patent No. 10,965,512

U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '512 patent. *E.g.*, The LTE release 8 standard and subsequent releases ("LTE") include an orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain. For example, the LTE specification (Series 36, Release 8) supports user equipment (UEs) to communicate with eNodeBs.

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U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

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4 Overall architecture

The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs.

The E-UTRAN architecture is illustrated in Figure 4 below.

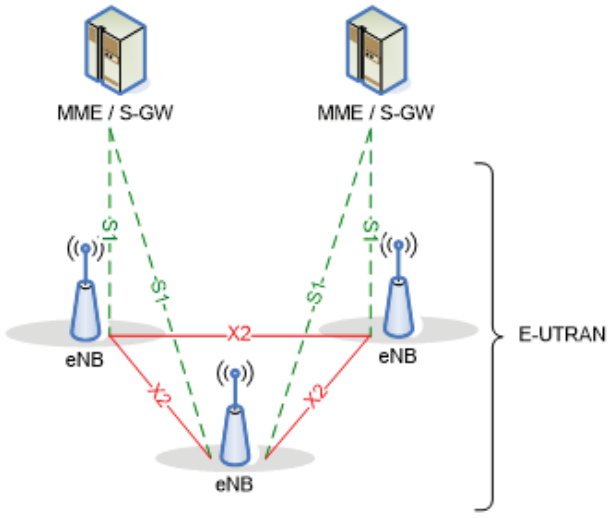


Figure 4-1: Overall Architecture

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 15.

LTE uses OFDMA in the downlink transmission.

U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

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5.1 Downlink Transmission Scheme

5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

In addition there is also a reduced sub-carrier spacing $\Delta f_{low} = 7.5$ kHz, only for MBMS-dedicated cell.

In the case of 15 kHz sub-carrier spacing there are two cyclic-prefix lengths, corresponding to seven and six OFDM symbols per slot respectively.

- Normal cyclic prefix: $T_{CP} = 160 \times Ts$ (OFDM symbol #0), $T_{CP} = 144 \times Ts$ (OFDM symbol #1 to #6)
- Extended cyclic prefix: $T_{CP\text{-}e} = 512 \times Ts$ (OFDM symbol #0 to OFDM symbol #5)

  where $T_s = 1/(2048 \times \Delta f)$

In case of 7.5 kHz sub-carrier spacing, there is only a single cyclic prefix length $T_{CP\text{-}low} = 1024 \times Ts$, corresponding to 3 OFDM symbols per slot.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

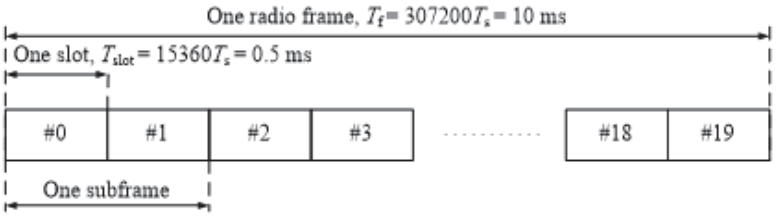
Each frame structure has time slots. For example, Frame structure type 1 for FDD includes 20 time slots.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10$ ms long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

249	For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.  **Figure 4.1-1: Frame structure type 1.** See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 9-10. The mobile station receives signals in the form of subcarriers having a time domain and frequency domain component. 6.2.1 Resource grid The transmitted signal in each slot is described by a resource grid of $N_{RB}^{DL}N_{sc}^{RB}$ subcarriers and N_{symb}^{DL} OFDM symbols. The resource grid structure is illustrated in Figure 6.2.2-1. The quantity N_{RB}^{DL} depends on the downlink transmission bandwidth configured in the cell and shall fulfil $$N_{RB}^{min,DL} \le N_{RB}^{DL} \le N_{RB}^{max,DL}$$ where $N_{RB}^{min,DL} = 6$ and $N_{RB}^{max,DL} = 110$ are the smallest and largest downlink bandwidth, respectively, supported by the current version of this specification.

U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

	The set of allowed values for N_{RB}^{DL} is given by [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1. In case of multi-antenna transmission, there is one resource grid defined per antenna port. An antenna port is defined by its associated reference signal. The set of antenna ports supported depends on the reference signal configuration in the cell: - Cell-specific reference signals, associated with non-MBSFN transmission, support a configuration of one, two, or four antenna ports and the antenna port number p shall fulfil $p=0$, $p \in \{0,1\}$, and $p \in \{0,1,2,3\}$, respectively. - MBSFN reference signals, associated with MBSFN transmission, are transmitted on antenna port $p=4$. - UE-specific reference signals are transmitted on antenna port $p=5$. See e.g., 3GPP TS 36.211 V8.9.0 at pg. 45. 6.2.2 Resource elements Each element in the resource grid for antenna port p is called a resource element and is uniquely identified by the index pair (k,l) in a slot where $k=0,\ldots,N_{RB}^{DL}N_{sc}^{RB}-1$ and $l=0,\ldots,N_{symb}^{DL}-1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.

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U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

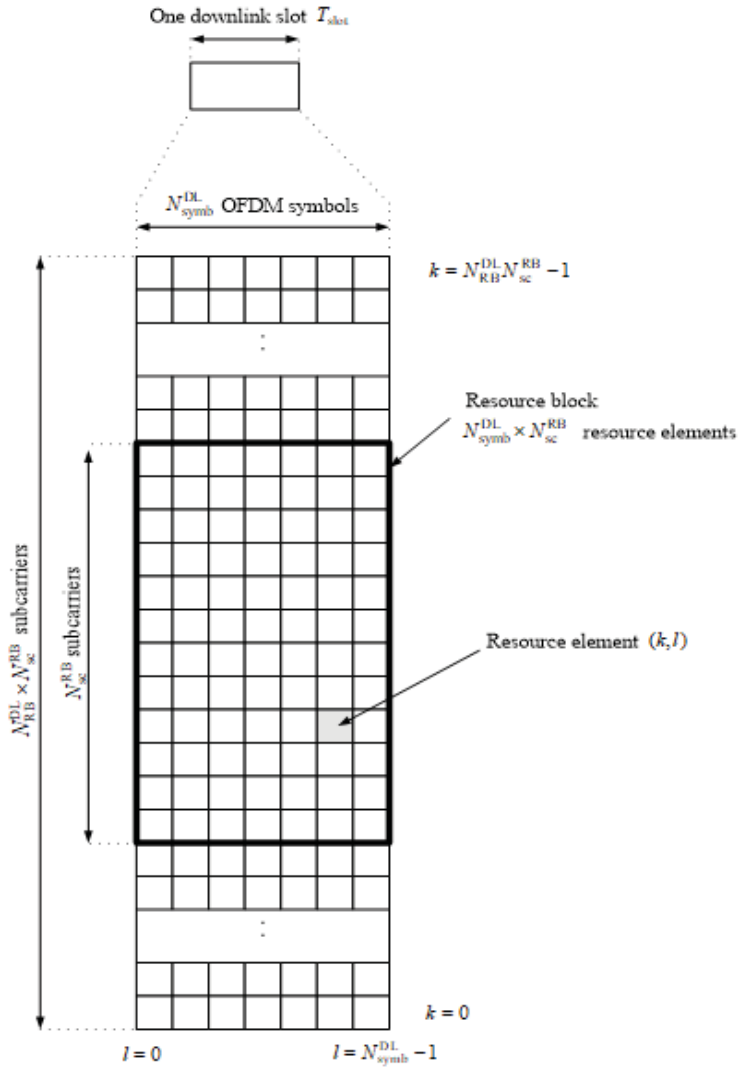


Figure 6.2.2-1: Downlink resource grid.

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 45-46.

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U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

A physical resource block (PRB) corresponds to a plurality of consecutive OFDM symbols in the time domain and a plurality of consecutive subcarriers in the frequency domain, which correspond to a block of resource elements. The block of resource elements correspond to one time slot in the time domain and 180 kHz in the frequency domain.

6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as N_{symb}^{DL} consecutive OFDM symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{DL} and N_{sc}^{RB} are given by Table 6.2.3-1. A physical resource block thus consists of $N_{symb}^{DL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to $N_{RB}^{DL} - 1$ in the frequency domain. The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

Table 6.2.3-1: Physical resource blocks parameters.

Configuration		N_{sc}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	$\Delta f = 15$ kHz	12	7
Extended cyclic prefix	$\Delta f = 15$ kHz		6
	$\Delta f = 7.5$ kHz	24	3

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 46-47.

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U.S. Patent No. 10,965,512: Claim 15(a)

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

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6.12 OFDM baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ on antenna port p in OFDM symbol l in a downlink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor}^{-1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi k \Delta f (t - N_{CP,l} T_s)} + \sum_{k=1}^{\lceil N_{RB}^{DL} N_{sc}^{RB}/2 \rceil} a_{k^{(+)},l}^{(p)} \cdot e^{j2\pi k \Delta f (t - N_{CP,l} T_s)}$$

for $0 \le t < (N_{CP,l} + N) \times T_s$ where $k^{(-)} = k + \lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor$ and $k^{(+)} = k + \lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor - 1$. The variable N equals 2048 for $\Delta f = 15$ kHz subcarrier spacing and 4096 for $\Delta f = 7.5$ kHz subcarrier spacing.

The OFDM symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where OFDM symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1} (N_{CP,l'} + N) T_s$ within the slot. In case the first OFDM symbol(s) in a slot use normal cyclic prefix and the remaining OFDM symbols use extended cyclic prefix, the starting position the OFDM symbols with extended cyclic prefix shall be identical to those in a slot where all OFDM symbols use extended cyclic prefix. Thus there will be a part of the time slot between the two cyclic prefix regions where the transmitted signal is not specified.

Table 6.12-1 lists the value of $N_{CP,l}$ that shall be used. Note that different OFDM symbols within a slot in some cases have different cyclic prefix lengths.

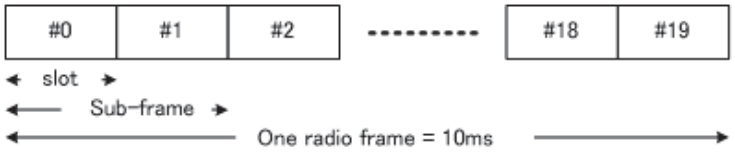
Table 6.12-1: OFDM parameters.

Configuration		Cyclic prefix length $N_{CP,l}$
Normal cyclic prefix	$\Delta f = 15$ kHz	160 for $l = 0$ 144 for $l = 1,2,...6$
Extended cyclic prefix	$\Delta f = 15$ kHz	512 for $l = 0,1,...5$
	$\Delta f = 7.5$ kHz	1024 for $l = 0,1,2$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 76.

U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to: receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;	Honda's Accused Products each include at least one antenna and a receiver, wherein the at least one antenna and the receiver are configured first and second pilots of first and second types, respectively. *E.g.*, The UE receives first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots and receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots. For example, the LTE UE receives cell-specific reference signals and UE-specific reference signals via at least one antenna on a plurality of subcarriers in at least one time slot. **5 Physical Layer for E-UTRA** Downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported: - Type 1, applicable to FDD, - Type 2, applicable to TDD. Frame structure Type 1 is illustrated in Figure 5.1-1. Each 10 ms radio frame is divided into ten equally sized sub-frames. Each sub-frame consists of two equally sized slots. For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain.  **Figure 5.1-1: Frame structure type 1** See e.g., 3GPP TS 36.300 V8.12.0 at pg. 23.

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U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

255	**6.10 Reference signals** Three types of downlink reference signals are defined: - Cell-specific reference signals, associated with non-MBSFN transmission - MBSFN reference signals, associated with MBSFN transmission - UE-specific reference signals There is one reference signal transmitted per downlink antenna port. See e.g., 3GPP TS 36.211 V8.9.0 at pg.65. The mapping of the cell-specific reference signals are to resource elements that correspond to a subcarrier and symbol in a slot. **6.10.1 Cell-specific reference signals** Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols. Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3. Cell-specific reference signals are defined for $\Delta f = 15$ kHz only. See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

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6.10.1.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols for antenna port p in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0,1,\ldots, 2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables v and v_{shift} define the position in the frequency domain for the different reference signals where v is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_s \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_s \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

Resource elements (k,l) used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

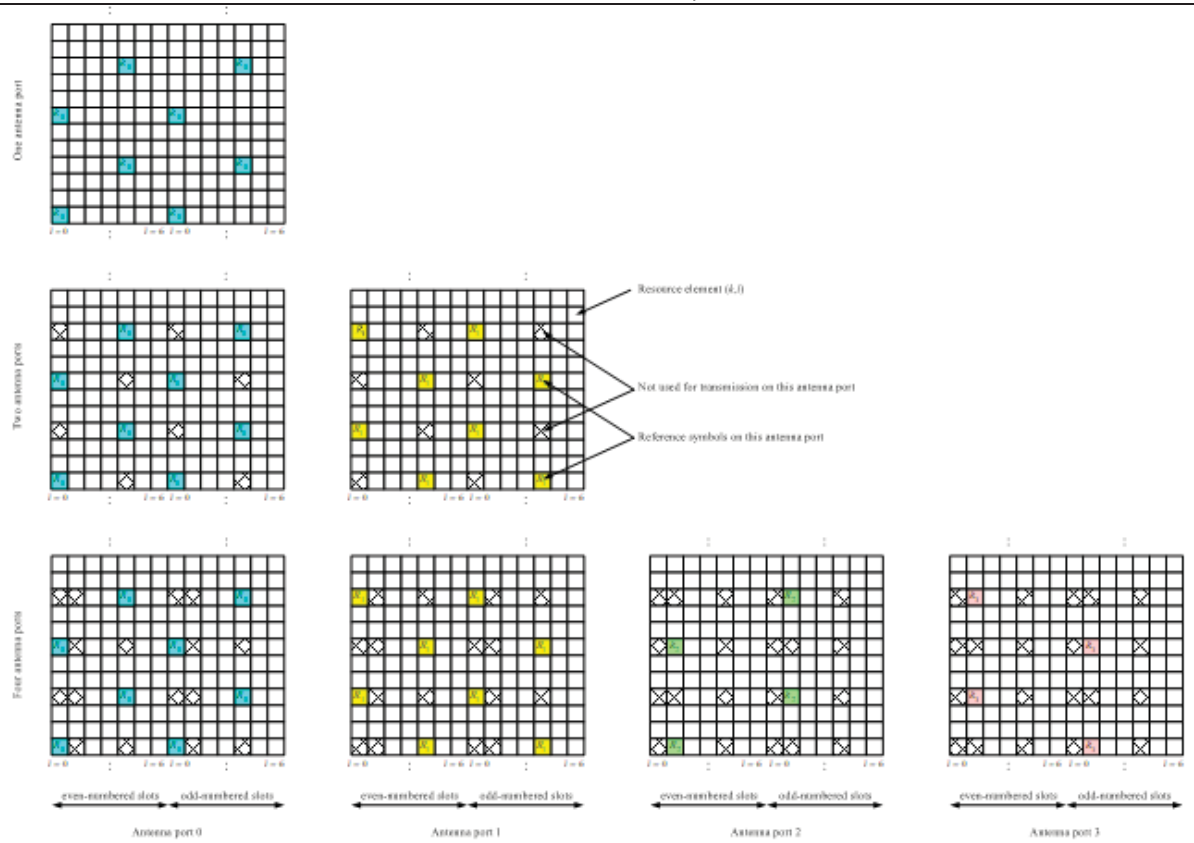


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).

See e.g., 3GPP TS 36.211 V8.9.0 at pg.66-67.

The UE-specific reference signals are transmitted on resource elements, which include the second plurality of subcarriers, upon which a corresponding PDSCH, data, is mapped.

6.10.3 UE-specific reference signals

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U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

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UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70.

6.10.3.2 Mapping to resource elements

In a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=5$ in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r(3\cdot l'\cdot N_{\text{RB}}^{\text{PDSCH}} + m')$$

$$k = (k') \bmod N_{\text{sc}}^{\text{RB}} + N_{\text{sc}}^{\text{RB}}\cdot n_{\text{PRB}}$$

$$k' = \begin{cases} 4m'+v_{\text{shift}} & \text{if } l\in\{2,3\} \\ 4\text{m}'+(2+v_{\text{shift}}) \bmod 4 & \text{if } l\in\{5,6\} \end{cases}$$

$$l = \begin{cases} 3 & l'=0 \\ 6 & l'=1 \\ 2 & l'=2 \\ 5 & l'=3 \end{cases}$$

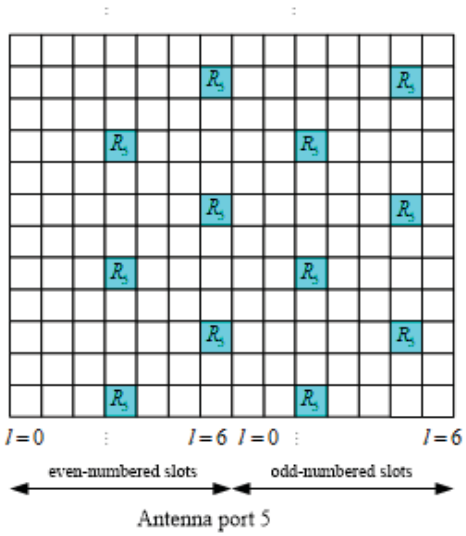
$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \\ 2,3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,3N_{\text{RB}}^{\text{PDSCH}}-1$$

...

U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

259	where m' is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission. The cell-specific frequency shift is given by $v_{shift} = N_{ID}^{cell} \bmod 3$. The mapping shall be in increasing order of the frequency-domain index n_{PRB} of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity N_{RB}^{PDSCH} denotes the bandwidth in resource blocks of the corresponding PDSCH transmission. Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix. Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.  **Figure 6.10.3.2-1: Mapping of UE-specific reference signals (normal cyclic prefix)** See e.g., 3GPP TS 36.211 V8.9.0 at pg.71-72

U.S. Patent No. 10,965,512: Claim 15(b)

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:
receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and
receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

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8.2.2 UE-Specific Reference Signals in Release 8

In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE.

A typical usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs. For example, rather than using the physical antennas used for transmission of the other (cell-specific) antenna ports, the eNodeB may use a correlated array of physical antenna elements to generate a narrow beam in the direction of a particular UE. Such a beam will experience a different channel response between the eNodeB and UE, thus requiring the use of UE-specific RSs to enable the UE to demodulate the beamformed data coherently. The use of UE-specific beamforming is discussed in more detail in Section 11.2.2.3.

As identified in [11], the structure shown in Figure 8.4 (for the normal CP) has been chosen because there is no collision with the cell specific RSs, and hence the presence of UE-specific RSs does not affect features related to the cell-specific RSs. The UE-specific RSs have a similar pattern to that of the cell-specific RSs, which allows a UE to re-use similar channel estimation algorithms. The density is half that of the cell-specific RS, hence minimizing the overhead. Unlike the cell-specific RSs, the sequence for the UE-specific RSs is only reinitialized at the start of each subframe, as the number of REs to which the sequence is mapped in one OFDM symbol may be very small (in the event of a small number of RBs being transmitted to a UE). The initialization depends on the UE's identity.

The corresponding pattern for use in case of the extended CP being configured in a cell can be found in [6, Section 6.10.3.2].

See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2nd Edition pg. 171.

U.S. Patent No. 10,965,512: Claim 15(c)

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and	At least some of the first or second plurality subcarriers used to receive the first or second pilots by Honda's Accused Products are beamformed. *E.g.*, For example, one of the usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs via the second plurality of subcarriers. **5.3 Transport Channels** The physical layer offers information transfer services to MAC and higher layers. The physical layer transport services are described by *how* and with what characteristics data are transferred over the radio interface. An adequate term for this is "Transport Channel". ... Downlink transport channel types are: 1. **Broadcast Channel (BCH)** characterised by: - fixed, pre-defined transport format; - requirement to be broadcast in the entire coverage area of the cell. 2. **Downlink Shared Channel (DL-SCH)** characterised by: - support for HARQ; - support for dynamic link adaptation by varying the modulation, coding and transmit power; - possibility to be broadcast in the entire cell; - possibility to use beamforming; ... See e.g., 3GPP TS 36.300 V8.12.0 at pg. 30. In LTE, subcarriers are beam-formed through precoding.

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U.S. Patent No. 10,965,512: Claim 15(e)

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

	6.3.4 Precoding The precoder takes as input a block of vectors $x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,\ldots, M_{\text{symb}}^{\text{layer}} - 1$ from the layer mapping and generates a block of vectors $y(i) = \left[\ldots \quad y^{(p)}(i) \quad \ldots\right]^T$, $i = 0,1,\ldots, M_{\text{symb}}^{\text{ap}} - 1$ to be mapped onto resources on each of the antenna ports, where $y^{(p)}(i)$ represents the signal for antenna port p. **6.3.4.1 Precoding for transmission on a single antenna port** For transmission on a single antenna port, precoding is defined by $$y^{(p)}(i) = x^{(0)}(i)$$ where $p \in \{0,4,5\}$ is the number of the single antenna port used for transmission of the physical channel and $i = 0,1,\ldots, M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. See e.g., 3GPP TS 36.211 V8.9.0 at pg. 52.

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U.S. Patent No. 10,965,512: Claim 15(c)

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

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8.2.2 UE-Specific Reference Signals in Release 8

In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE.

A typical usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs. For example, rather than using the physical antennas used for transmission of the other (cell-specific) antenna ports, the eNodeB may use a correlated array of physical antenna elements to generate a narrow beam in the direction of a particular UE. Such a beam will experience a different channel response between the eNodeB and UE, thus requiring the use of UE-specific RSs to enable the UE to demodulate the beamformed data coherently. The use of UE-specific beamforming is discussed in more detail in Section 11.2.2.3.

As identified in [11], the structure shown in Figure 8.4 (for the normal CP) has been chosen because there is no collision with the cell specific RSs, and hence the presence of UE-specific RSs does not affect features related to the cell-specific RSs. The UE-specific RSs have a similar pattern to that of the cell-specific RSs, which allows a UE to re-use similar channel estimation algorithms. The density is half that of the cell-specific RS, hence minimizing the overhead. Unlike the cell-specific RSs, the sequence for the UE-specific RSs is only reinitialized at the start of each subframe, as the number of REs to which the sequence is mapped in one OFDM symbol may be very small (in the event of a small number of RBs being transmitted to a UE). The initialization depends on the UE's identity.

The corresponding pattern for use in case of the extended CP being configured in a cell can be found in [6, Section 6.10.3.2].

See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2nd Edition pg. 171.

U.S. Patent No. 10,965,512: Claim 15(d)
"the receiver is further configured to:
recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

the receiver is further configured to: recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;	The receiver of Honda's Accused Products is further configured to recover the data using channel estimates and cell-specific information using the pilots. *E.g.*, The UE is further configured to recover the data using channel estimates from at least the second pilots and recover cell-specific information using the cell-specific pilots. For example, the LTE UE uses the UE-specific reference signals embedded in the received PRBs to derive the channel estimation for demodulating the data in the corresponding PDSCH resource blocks. 6.10.3 UE-specific reference signals UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p. See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70. **8.2.2 UE-Specific Reference Signals in Release 8** In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE. See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2nd Edition pg. 171.

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U.S. Patent No. 10,965,512: Claim 15(d)
"the receiver is further configured to:
recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

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The LTE UE recovers cell-specific information, such as the cell ID, using the cell-specific pilots. The Cell ID (N_{ID}^{cell}) is used for generating the cell-specific reference signal sequence.

6.10.1.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,\ldots,2N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}} = 2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{ID}^{cell}+1)+2\cdot N_{ID}^{cell}+N_{CP}$ at the start of each OFDM symbol where

$$N_{CP} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

See e.g., 3GPP TS 36.211 V8.9.0 at pgs.65-66.

The LTE cell-specific reference signal is also used to recover cell-specific information from the *MasterInformationBlock*, which is transmitted via the broadcast channel (BCH). The cell-specific reference signal is used, *inter alia*, to estimate the channel corresponding to the center part of the carrier where the BCH is transmitted.

– *MasterInformationBlock*

The *MasterInformationBlock* includes the system information transmitted on BCH.

U.S. Patent No. 10,965,512: Claim 15(d)
"the receiver is further configured to:
recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

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Signalling radio bearer: N/A

RLC-SAP: TM

Logical channel: BCCH

Direction: E-UTRAN to UE

MasterInformationBlock

```
-- ASN1START

MasterInformationBlock ::=          SEQUENCE {
    dl-Bandwidth                        ENUMERATED {
                                            n6, n15, n25, n50, n75, n100},
    phich-Config                        PHICH-Config,
    systemFrameNumber                   BIT STRING (SIZE (8)),
    spare                               BIT STRING (SIZE (10))
}


-- ASN1STOP
```

***MasterInformationBlock* field descriptions**
dl-Bandwidth Parameter: transmission bandwidth configuration, N_{RB} in downlink, see TS 36.101 [42, table 5.6-1]. n6 corresponds to 6 resource blocks, n15 to 15 resource blocks and so on.
systemFrameNumber Defines the 8 most significant bits of the SFN, see TS 36.211 [21, 6.6.1]. The 2 least significant bits of the SFN are acquired implicitly in the P-BCH decoding, i.e. timing of 40ms P-BCH TTI indicates 2 least significant bits (within 40ms P-BCH TTI, the first radio frame: 00, the second radio frame: 01, the third radio frame: 10, the last radio frame: 11).

See e.g., 3GPP TS 36.331 V8.21.0 at pgs.85-86.

ceiving neighbor-cell [illegible]

4G, LTE-ADVANCED PRO AND THE ROAD TO 5G

6.2.1. Cell-Specific Reference Signals

U.S. Patent No. 10,965,512: Claim 15(d)
"the receiver is further configured to:
recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

	In general, the values of the reference symbols vary between different reference-symbol positions and also between different cells. Thus, a CRS can be seen as a two-dimensional cell-specific sequence. The period of this sequence equals one 10 ms frame. Furthermore, regardless of the cell bandwidth, the reference-signal sequence is defined assuming the maximum possible LTE carrier bandwidth corresponding to 110 resource blocks in the frequency domain. Thus, the basic reference-signal sequence has a length of 8800 symbols.[2] For cell bandwidths less than the maximum possible value, only the reference symbols within that bandwidth are actually transmitted. The reference symbols in the center part of the band will therefore be the same, regardless of the actual cell bandwidth. This allows for the device to estimate the channel corresponding to the center part of the carrier, where, for example, the basic system information of the cell is transmitted on the BCH transport channel, without knowing the cell bandwidth. Information about the actual cell bandwidth, measured as number of resource blocks, is then provided on the BCH. See e.g., 4G, LTE ADVANCED PRO AND THE ROAD TO 5G, Third Edition, pg. 104

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U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.	The second type of pilots used with Honda's Accused Products are different than the first type of pilots and the first pilots do not interfere with the second pilots. *E.g.*, For example, cell-specific reference signals, the first pilots, are different than the UE-specific reference signals, second pilots. **6.10 Reference signals** Three types of downlink reference signals are defined: - Cell-specific reference signals, associated with non-MBSFN transmission - MBSFN reference signals, associated with MBSFN transmission - UE-specific reference signals There is one reference signal transmitted per downlink antenna port. See e.g., 3GPP TS 36.211 V8.9.0 at pg.65. The UE-specific reference signals are not transmitted in resource elements in which other physical signals, such as the cell-specific reference signal, are transmitted. Thus, they do not interfere. **6.10.3 UE-specific reference signals** UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p. See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70.

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U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

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6.10.3.2 Mapping to resource elements

In a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=5$ in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r(3 \cdot l' \cdot N_{RB}^{PDSCH} + m')$$

$$k = (k') \bmod N_{sc}^{RB} + N_{sc}^{RB} \cdot n_{PRB}$$

$$k' = \begin{cases} 4m' + v_{shift} & \text{if } l \in \{2,3\} \\ 4m' + (2 + v_{shift}) \bmod 4 & \text{if } l \in \{5,6\} \end{cases}$$

$$l = \begin{cases} 3 & l' = 0 \\ 6 & l' = 1 \\ 2 & l' = 2 \\ 5 & l' = 3 \end{cases}$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \\ 2,3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,3N_{RB}^{PDSCH} - 1$$

...

where m' is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

The cell-specific frequency shift is given by $v_{shift} = N_{ID}^{cell} \bmod 3$.

The mapping shall be in increasing order of the frequency-domain index n_{PRB} of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity N_{RB}^{PDSCH} denotes the bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix.

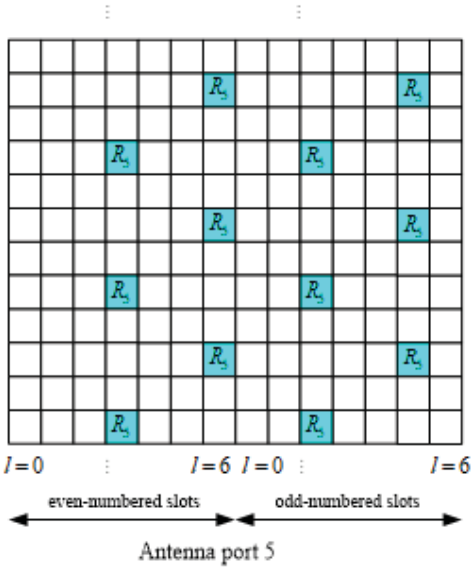
Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

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The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.



Antenna port 5

See e.g., 3GPP TS 36.211 V8.9.0 at pg.71-72

6.10.1 Cell-specific reference signals

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for $\Delta f = 15$ kHz only.

See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

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6.10.1.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols for antenna port p in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0,1,\ldots, 2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables v and v_{shift} define the position in the frequency domain for the different reference signals where v is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_s \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_s \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

Resource elements (k,l) used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

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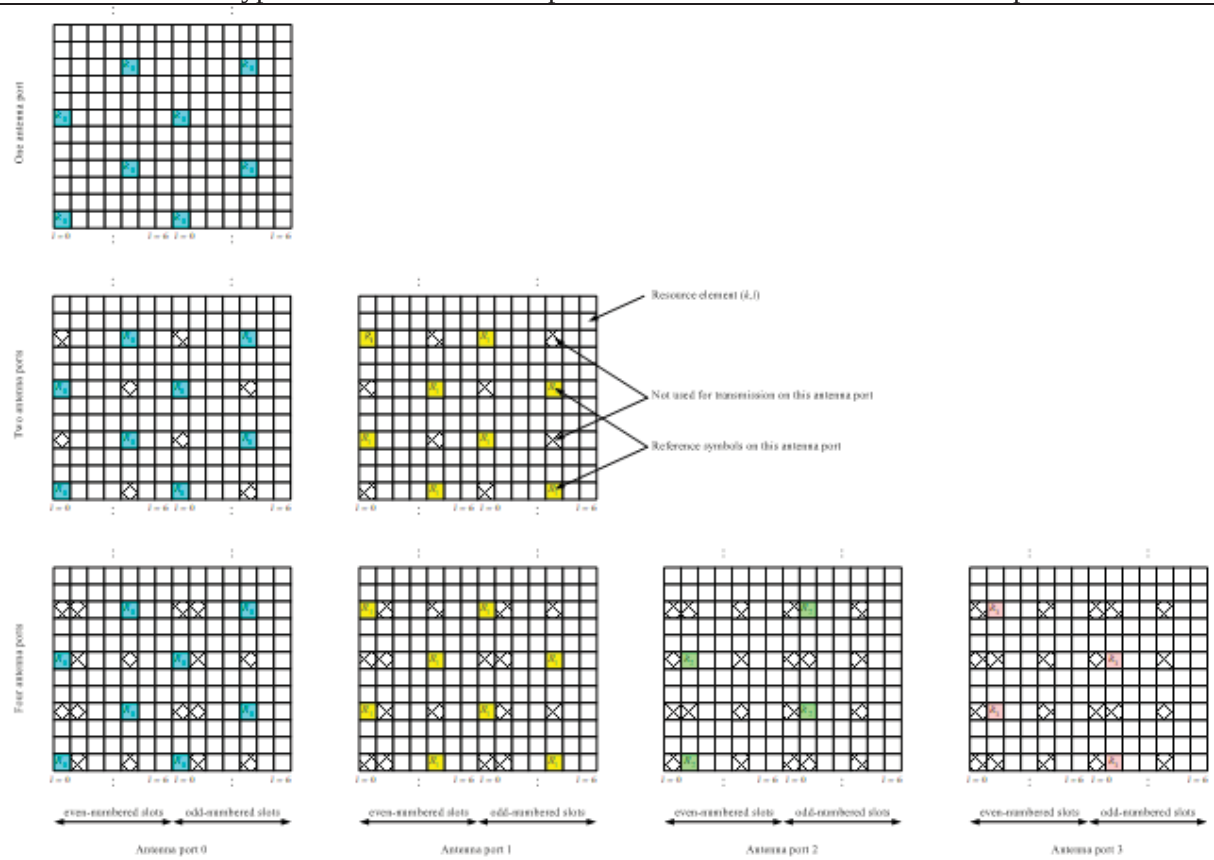


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).

See e.g., 3GPP TS 36.211 V8.9.0 at pg.66-67.

Exhibit 12

Exhibit 12
Claim 23 of U.S. Patent No. 10,771,302

U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:	Honda's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Honda. To the extent the preamble is considered a limitation, Honda's Accused Products meet the preamble of the '302 patent. *E.g.*, The LTE specification (Series 36, Release 8) supports user equipment (UE) to perform a sounding reference signal (SRS) procedure. For example, release 8 of the 36 series 3GPP specifications was frozen in December of 2008 and that release was used as the basis for the first wave of LTE equipment. The LTE marketplace currently supports a mix of releases from Release 8 through Release 15. For ease of review release 8 of the LTE specification is cited below, but similar cites are available for each corresponding release on the market. An LTE communication system has user equipments (UEs) transmit to and receive signals from eNodeBs.

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U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

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4 Overall architecture

The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs.

The E-UTRAN architecture is illustrated in Figure 4 below.

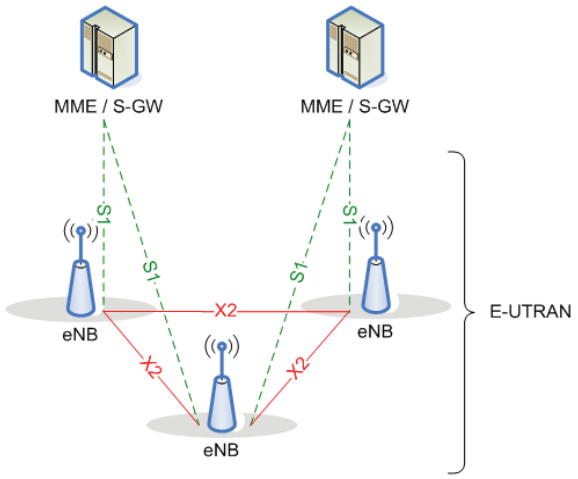


Figure 4-1: Overall Architecture

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 15.

U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

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4.3.1 User plane

The figure below shows the protocol stack for the user-plane, where PDCP, RLC and MAC sublayers (terminated in eNB on the network side) perform the functions listed for the user plane in subclause 6, e.g. header compression, ciphering, scheduling, ARQ and HARQ;

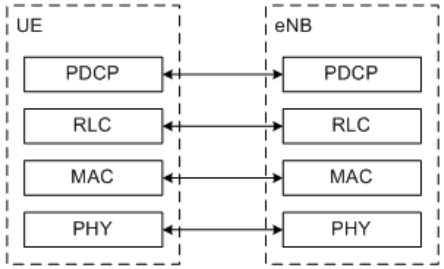


Figure 4.3.1-1: User-plane protocol stack

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 18.

LTE uses OFDM for both the downlink and the uplink. For the uplink, LTE uses a specific type of OFDM referred to a discrete Fourier Transform Spread (DFTS)-OFDM.

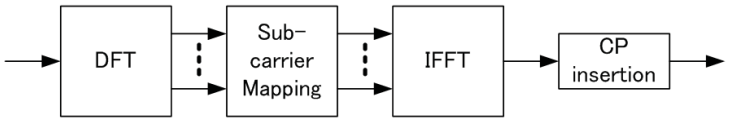
5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is $\Delta f = 15$ kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min} = 6$ to $N_{RB\text{-}max} = 110$.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

	5.2.1 Basic transmission scheme For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.  **Figure 5.2.1-1: Transmitter scheme of SC-FDMA** See e.g., 3GPP TS 36.300 V8.12.0 at pg. 27.

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U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

LTE uses an uplink channel bandwidth divided into physical resource blocks.

5.6 Channel bandwidth

Requirements in present document are specified for the channel bandwidths listed in Table 5.6-1.

Table 5.6-1 Transmission bandwidth configuration N_{RB} in E-UTRA channel bandwidths

Channel bandwidth $BW_{Channel}$ [MHz]	1.4	3	5	10	15	20
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

Figure 5.6-1 shows the relation between the Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$/2.

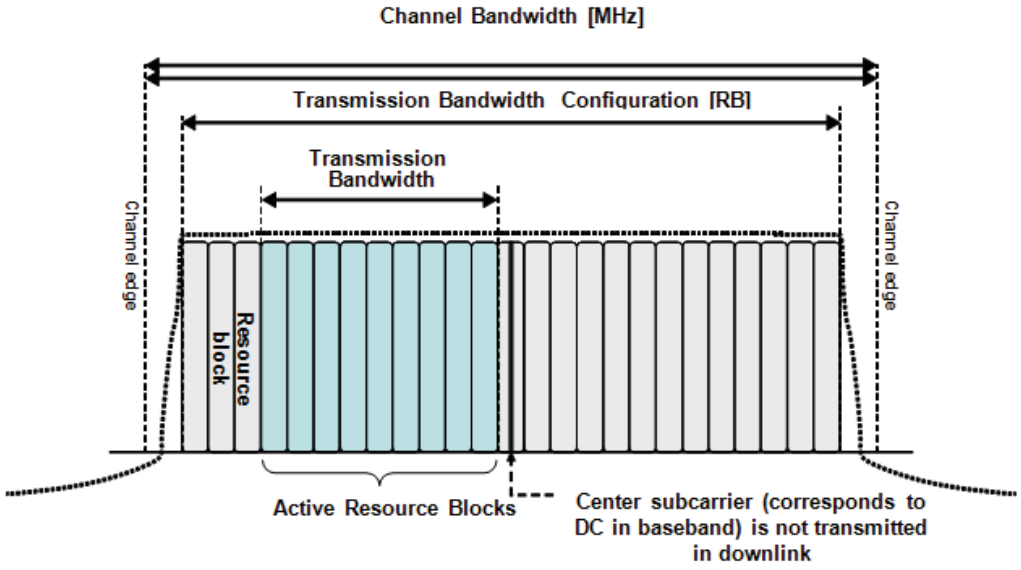


Figure 5.6-1 Definition of Channel Bandwidth and Transmission Bandwidth Configuration for one E-UTRA carrier

See e.g., 3GPP TS 36.101 V8.29.0 at pg. 15.

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U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

Each physical resource block (PRB) has 12 subcarriers.

5.2.3 Resource blocks

A physical resource block is defined as N_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	N_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 13.

IP packets, voice and other user plane data is sent over dedicated traffic channels (DTCHs), which are sent over the uplink shared channel (UL-SCH) transport channel.

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U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

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6.1.2.2 Traffic Channels

Traffic channels are used for the transfer of user plane information only. The traffic channels offered by MAC are:

- **Dedicated Traffic Channel (DTCH)**

  A Dedicated Traffic Channel (DTCH) is a point-to-point channel, dedicated to one UE, for the transfer of user information. A DTCH can exist in both uplink and downlink.

6.1.3 Mapping between logical channels and transport channels

6.1.3.1 Mapping in Uplink

The figure below depicts the mapping between uplink logical channels and uplink transport channels:

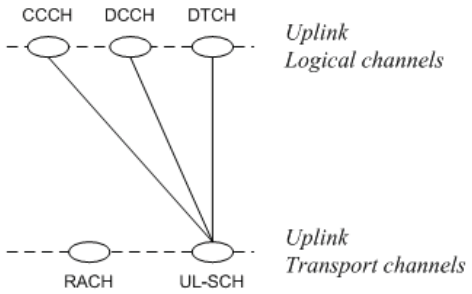


Figure 6.1.3.1-1: Mapping between uplink logical channels and uplink transport channels

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 34.

U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

The UL-SCH transport channel is sent over the physical uplink shared channel (PUSCH) and control is sent over the physical uplink control channel (PUCCH).

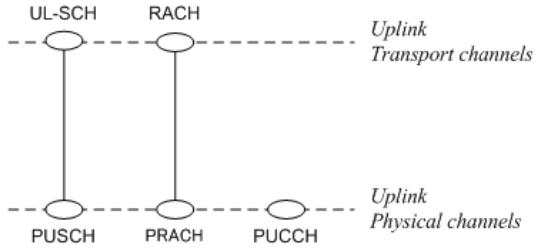


Figure 5.3.1-2: Mapping between uplink transport channels and uplink physical channels

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 31.

5.4 Physical uplink control channel

The physical uplink control channel, PUCCH, carries uplink control information. The PUCCH is never transmitted simultaneously with the PUSCH from the same UE. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 16.

The PUCCH is transmitted using the outer PRBs/subcarriers of the uplink bandwidth and the PUSCH is transmitted using the PRBs/subcarriers between the PUCCH subcarriers.

5.4.3 Mapping to physical resources

The block of complex-valued symbols $z(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Section 5.1.2.1 in [4], and mapped in sequence starting with $z(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z(i)$ to resource elements (k,l) not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 20.

U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

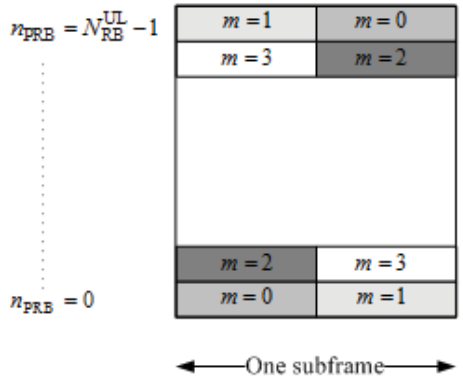


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 21.

7.4.1.6. Resource-Block Mapping for PUCCH

The signals described for all of the PUCCH formats are, as already explained, transmitted on a (set of) resource-block pair. The resource-block pair to use is determined from the PUCCH resource index. Multiple resource-block pairs can be used to increase the control-signaling capacity in the cell; when one resource-block pair is full, the next PUCCH resource index is mapped to the next resource-block pair in sequence.

The resource-block pair(s) where a PUCCH is transmitted is located at the edges of the bandwidth allocated to the primary component carrier[23] as illustrated in Figure 7.28. To provide frequency diversity, frequency hopping on the slot boundary is used—that is, one "frequency resource" consists of 12 (or more in case of PUCCH format 4) subcarriers at the upper part of the spectrum within the first slot of a subframe and an equally sized resource at the lower part of the spectrum during the second slot of the subframe (or vice versa).

The reason for locating the PUCCH resources at the edges of the overall available spectrum is twofold:

- Together with the frequency hopping described previously, this maximizes the frequency diversity experienced by the control signaling.
- Assigning uplink resources for the PUCCH at other positions within the spectrum—that is, not at the edges—would have fragmented the uplink spectrum, making it impossible to assign very wide transmission bandwidths to a single device and still preserve the low-cubic-metric properties of the uplink transmission.

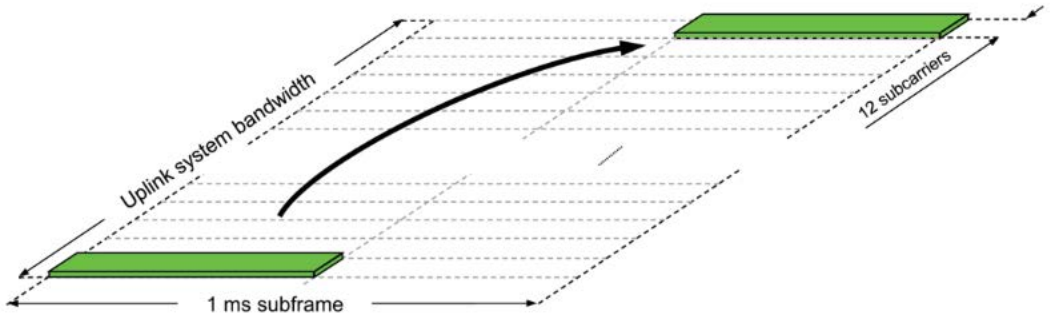


Figure 7.28 Uplink L1/L2 control signaling transmission on PUCCH.

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U.S. Patent No. 10,771,302: Claim 23(a)

"23. A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:"

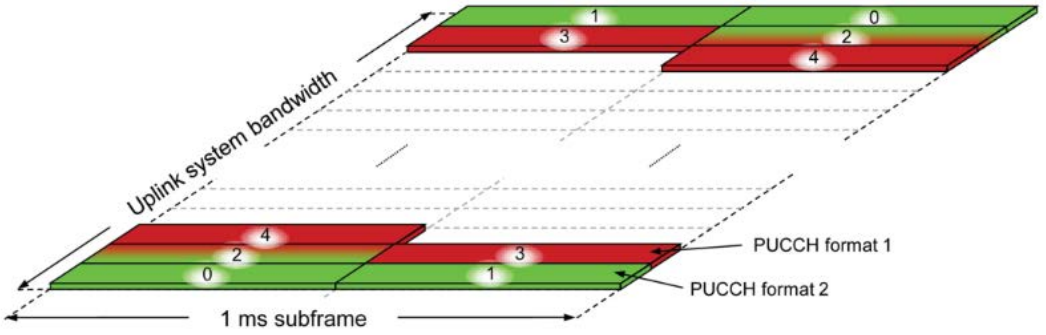


Figure 7.29 Allocation of resource blocks for PUCCH.

The resource-block mapping is in principle done such that PUCCH format 2 (CSI reports) is transmitted closest to the edges of the uplink cell bandwidth with PUCCH format 1 (hybrid-ARQ acknowledgments, scheduling requests) next as illustrated in Figure 7.29. The locations of PUCCH formats 3, 4, and 5 are configurable and can, for example, be located between formats 1 and 2. A semi-static parameter, provided as part of the system information, controls on which resource-block pair the mapping of PUCCH format 1 starts. Furthermore, the semi-statically configured scheduling requests are located at the outermost parts of the format 1 resources, leaving dynamic acknowledgments closest to the data. As the amount of resources necessary for hybrid-ARQ acknowledgments varies dynamically, this maximizes the amount of contiguous spectrum available for PUSCH.

In many scenarios, the configuration of the PUCCH resources can be done such that the three PUCCH formats are transmitted on separate sets of resource blocks. However, for the smallest cell bandwidths, this would result in too high an overhead. Therefore, it is possible to mix PUCCH formats 1 and 2 in one of the resource-block pairs—for example, in Figure 7.29 this is the case for the resource-block pair denoted "2." Although this mixture is primarily motivated by the smaller cell bandwidths, it can equally well be used for the larger cell bandwidths. In the resource-block pair where PUCCH formats 1 and 2 are mixed, the set of possible phase rotations are split between the two formats. Furthermore, some of the phase rotations are reserved as "guard"; hence the efficiency of such a mixed resource-block pair is slightly lower than a resource-block pair carrying only one of the first two PUCCH formats.

See e.g., 4G LTE=Advanced Pro and The Road to 5G, Third Edition, Dahlman et al, §7.4.1.6.

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U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

a receiver configured to receive a request for a probing signal from a base station in the system;	Honda's Accused Products include a receiver configured to receive a request for a probing signal from a base station in the system. *E.g.*, For example, for periodic SRS the UE receives from the eNB an RRC message (RRCConnectionReconfiguration message or SystemInformation message) including SRS configuration parameters in the *SoundingRS-UL-Config* information element, which instructs the UE to periodically transmit SRS. – *RRCConnectionReconfiguration* The *RRCConnectionReconfiguration* message is the command to modify an RRC connection. It may convey information for measurement configuration, mobility control, radio resource configuration (including RBs, MAC main configuration and physical channel configuration) including any associated dedicated NAS information and security configuration. Signalling radio bearer: SRB1 RLC-SAP: AM Logical channel: DCCH Direction: E-UTRAN to UE ***RRCConnectionReconfiguration* message** `-- ASN1START` `RRCConnectionReconfiguration ::= SEQUENCE {` `  rrc-TransactionIdentifier  RRC-TransactionIdentifier,` `  criticalExtensions  CHOICE {` `  c1  CHOICE{` `  rrcConnectionReconfiguration-r8  RRCConnectionReconfiguration-r8-IEs,` `  spare7 NULL,` `  spare6 NULL, spare5 NULL, spare4 NULL,` `  spare3 NULL, spare2 NULL, spare1 NULL` `  },` `  criticalExtensionsFuture  SEQUENCE {}` `  }` `}` `RRCConnectionReconfiguration-r8-IEs ::= SEQUENCE {` `  measConfig  MeasConfig  OPTIONAL,  -- Need ON` `  mobilityControlInfo  MobilityControlInfo  OPTIONAL,  -- Cond HO` `  dedicatedInfoNASList  SEQUENCE (SIZE(1..maxDRB)) OF` `  DedicatedInfoNAS  OPTIONAL,  -- Cond nonHO` `  radioResourceConfigDedicated  RadioResourceConfigDedicated  OPTIONAL,  -- Cond HO-toEUTRA` `  securityConfigHO  SecurityConfigHO  OPTIONAL,  -- Cond HO` `  nonCriticalExtension  SEQUENCE {}  OPTIONAL  -- Need OP` `}`

U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

See e.g., 3GPP TS 36.331 V8.21.0 at p. 89.

– *RadioResourceConfigDedicated*

The IE *RadioResourceConfigDedicated* is used to setup/modify/release RBs, to modify the MAC main configuration, to modify the SPS configuration and to modify dedicated physical configuration.

***RadioResourceConfigDedicated* information element**

```
-- ASN1START

RadioResourceConfigDedicated ::=        SEQUENCE {
    srb-ToAddModList                    SRB-ToAddModList            OPTIONAL,       -- Cond HO-Conn
    drb-ToAddModList                    DRB-ToAddModList            OPTIONAL,       -- Cond HO-
toEUTRA
    drb-ToReleaseList                   DRB-ToReleaseList           OPTIONAL,       -- Need ON
    mac-MainConfig                      CHOICE {
            explicitValue                   MAC-MainConfig,
            defaultValue                    NULL
    }       OPTIONAL,                                                               -- Cond HO-
toEUTRA2
    sps-Config                          SPS-Config                  OPTIONAL,       -- Need ON
    physicalConfigDedicated             PhysicalConfigDedicated     OPTIONAL,       -- Need ON
    ...
}
```

See e.g., 3GPP TS 36.331 V8.21.0 at p. 129.

– *PhysicalConfigDedicated*

The IE *PhysicalConfigDedicated* is used to specify the UE specific physical channel configuration.

***PhysicalConfigDedicated* information element**

```
-- ASN1START

PhysicalConfigDedicated ::=         SEQUENCE {
    pdsch-ConfigDedicated               PDSCH-ConfigDedicated           OPTIONAL,       -- Need ON
    pucch-ConfigDedicated               PUCCH-ConfigDedicated           OPTIONAL,       -- Need ON
    pusch-ConfigDedicated               PUSCH-ConfigDedicated           OPTIONAL,       -- Need ON
    uplinkPowerControlDedicated         UplinkPowerControlDedicated     OPTIONAL,       -- Need ON
    tpc-PDCCH-ConfigPUCCH               TPC-PDCCH-Config                OPTIONAL,       -- Need ON
    tpc-PDCCH-ConfigPUSCH               TPC-PDCCH-Config                OPTIONAL,       -- Need ON
    cqi-ReportConfig                    CQI-ReportConfig                OPTIONAL,       -- Need ON
    soundingRS-UL-ConfigDedicated       SoundingRS-UL-ConfigDedicated   OPTIONAL,       -- Need ON
    antennaInfo                         CHOICE {
        explicitValue                       AntennaInfoDedicated,
        defaultValue                        NULL
    }       OPTIONAL,                                                               -- Need ON
    schedulingRequestConfig             SchedulingRequestConfig         OPTIONAL,       -- Need ON
    ...
}

-- ASN1STOP
```

See e.g., 3GPP TS 36.331 V8.21.0 at p. 122.

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U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

Direction: E-UTRAN to UE

***SystemInformation* message**

```
-- ASN1START

SystemInformation ::=               SEQUENCE {
    criticalExtensions                  CHOICE {
        systemInformation-r8                SystemInformation-r8-IEs,
        criticalExtensionsFuture            SEQUENCE {}
    }
}
SystemInformation-r8-IEs ::=        SEQUENCE {
    sib-TypeAndInfo                     SEQUENCE (SIZE (1..maxSIB)) OF CHOICE {
        sib2                                SystemInformationBlockType2,
        sib3                                SystemInformationBlockType3,
        sib4                                SystemInformationBlockType4,
        sib5                                SystemInformationBlockType5,
        sib6                                SystemInformationBlockType6,
        sib7                                SystemInformationBlockType7,
        sib8                                SystemInformationBlockType8,
        sib9                                SystemInformationBlockType9,
        sib10                               SystemInformationBlockType10,
        sib11                               SystemInformationBlockType11,
        ...
    },
    nonCriticalExtension                SEQUENCE {}                         OPTIONAL    -- Need OP
}

-- ASN1STOP
```

See e.g., 3GPP TS 36.331 V8.21.0 at p. 100.

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U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

6.3.1 System information blocks

– *SystemInformationBlockType2*

The IE *SystemInformationBlockType2* contains radio resource configuration information that is common for all UEs.

NOTE: UE timers and constants related to functionality for which parameters are provided in another SIB are included in the corresponding SIB.

***SystemInformationBlockType2* information element**

```
-- ASN1START

SystemInformationBlockType2 ::=     SEQUENCE {
    ac-BarringInfo                      SEQUENCE {
        ac-BarringForEmergency              BOOLEAN,
        ac-BarringForMO-Signalling          AC-BarringConfig                OPTIONAL,   -- Need OP
        ac-BarringForMO-Data                AC-BarringConfig                OPTIONAL    -- Need OP
    }                                                                       OPTIONAL,   -- Need OP
    radioResourceConfigCommon           RadioResourceConfigCommonSIB,
    ue-TimersAndConstants               UE-TimersAndConstants,
    freqInfo                            SEQUENCE {
        ul-CarrierFreq                      ARFCN-ValueEUTRA                OPTIONAL,   -- Need OP
        ul-Bandwidth                        ENUMERATED {n6, n15, n25, n50, n75, n100}
                                                                            OPTIONAL,   -- Need OP
        additionalSpectrumEmission          AdditionalSpectrumEmission
    },
    mbsfn-SubframeConfigList            MBSFN-SubframeConfigList            OPTIONAL,   -- Need OR
    timeAlignmentTimerCommon            TimeAlignmentTimer,
    ...,
    lateNonCriticalExtension        OCTET STRING (CONTAINING SystemInformationBlockType2-v8h0-IEs)
                        OPTIONAL    -- Need OP
}
```

See e.g., 3GPP TS 36.331 V8.21.0 at p. 105.

U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

***RadioResourceConfigCommon* information element**

```
-- ASN1START

RadioResourceConfigCommonSIB ::=    SEQUENCE {
    rach-ConfigCommon                   RACH-ConfigCommon,
    bcch-Config                         BCCH-Config,
    pcch-Config                         PCCH-Config,
    prach-Config                        PRACH-ConfigSIB,
    pdsch-ConfigCommon                  PDSCH-ConfigCommon,
    pusch-ConfigCommon                  PUSCH-ConfigCommon,
    pucch-ConfigCommon                  PUCCH-ConfigCommon,
    soundingRS-UL-ConfigCommon          SoundingRS-UL-ConfigCommon,
    uplinkPowerControlCommon            UplinkPowerControlCommon,
    ul-CyclicPrefixLength               UL-CyclicPrefixLength,
    ...
}

RadioResourceConfigCommon ::=       SEQUENCE {
    rach-ConfigCommon                   RACH-ConfigCommon                   OPTIONAL,   -- Need ON
    prach-Config                        PRACH-Config,
    pdsch-ConfigCommon                  PDSCH-ConfigCommon                  OPTIONAL,   -- Need ON
    pusch-ConfigCommon                  PUSCH-ConfigCommon,
    phich-Config                        PHICH-Config                        OPTIONAL,   -- Need ON
    pucch-ConfigCommon                  PUCCH-ConfigCommon                  OPTIONAL,   -- Need ON
    soundingRS-UL-ConfigCommon          SoundingRS-UL-ConfigCommon          OPTIONAL,   -- Need ON
    uplinkPowerControlCommon            UplinkPowerControlCommon            OPTIONAL,   -- Need ON
    antennaInfoCommon                   AntennaInfoCommon           OPTIONAL,   -- Need ON
    p-Max                               P-Max                               OPTIONAL,   -- Need OP
    tdd-Config                          TDD-Config                          OPTIONAL,   -- Cond TDD
    ul-CyclicPrefixLength               UL-CyclicPrefixLength,
    ...
}
```

See e.g., 3GPP TS 36.331 V8.21.0 at p. 128.

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U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

– *SoundingRS-UL-Config*

The IE *SoundingRS-UL-Config* is used to specify the uplink Sounding RS configuration.

***SoundingRS-UL-Config* information element**

```
-- ASN1START

SoundingRS-UL-ConfigCommon ::=      CHOICE {
    release                             NULL,
    setup                               SEQUENCE {
        srs-BandwidthConfig                 ENUMERATED {bw0, bw1, bw2, bw3, bw4, bw5, bw6, bw7},
        srs-SubframeConfig                  ENUMERATED {
                                                sc0, sc1, sc2, sc3, sc4, sc5, sc6, sc7,
                                                sc8, sc9, sc10, sc11, sc12, sc13, sc14, sc15},
        ackNackSRS-SimultaneousTransmission BOOLEAN,
        srs-MaxUpPts                        ENUMERATED {true}           OPTIONAL    -- Cond TDD
    }
}

SoundingRS-UL-ConfigDedicated ::=   CHOICE{
    release                             NULL,
    setup                               SEQUENCE {
        srs-Bandwidth                       ENUMERATED {bw0, bw1, bw2, bw3},
        srs-HoppingBandwidth                ENUMERATED {hbw0, hbw1, hbw2, hbw3},
        freqDomainPosition                  INTEGER (0..23),
        duration                            BOOLEAN,
        srs-ConfigIndex                     INTEGER (0..1023),
        transmissionComb                    INTEGER (0..1),
        cyclicShift                         ENUMERATED {cs0, cs1, cs2, cs3, cs4, cs5, cs6, cs7}
    }
}


-- ASN1STOP
```

3GPP TS 36.331 V8.21.0 at p. 132.

For LTE-A UEs, those UEs can also be instructed to send an aperiodic SRS by the eNB as part of downlink control information (DCI) formats 0, 1A, 2B, 2C, and 4.

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling

- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C for TDD.

See e.g., 3GPP TS 36.213 V10.13.0 at pg. 81.

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U.S. Patent No. 10,771,302: Claim 23(b)

" a receiver configured to receive a request for a probing signal from a base station in the system;"

	- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3] See e.g., 3GPP TS 36.212 V10.9.0 at pg. 58. - SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PDSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3] See e.g., 3GPP TS 36.212 V10.9.0 at pg. 60.

U.S. Patent No. 10,771,302: Claim 23(c)

"a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:"

a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:	Honda's Accused Products each include a transmitter configured to form and transmit the probing signal with a code sequence modulated in the frequency domain. *E.g.*, For example, in response to the RRC signaling (periodic SRS) or the SRS request (aperiodic SRS), the UE generates a phase shifted SRS sequence that is modulated onto subcarriers in the frequency domain. **5.5 Reference signals** Two types of uplink reference signals are supported: - Demodulation reference signal, associated with transmission of PUSCH or PUCCH - Sounding reference signal, not associated with transmission of PUSCH or PUCCH The same set of base sequences is used for demodulation and sounding reference signals. **5.5.1 Generation of the reference signal sequence** Reference signal sequence $r_{u,v}^{(\alpha)}(n)$ is defined by a cyclic shift α of a base sequence $\bar{r}_{u,v}(n)$ according to $$r_{u,v}^{(\alpha)}(n) = e^{j\alpha n}\bar{r}_{u,v}(n), \quad 0 \le n < M_{sc}^{RS}$$ where $M_{sc}^{RS} = mN_{sc}^{RB}$ is the length of the reference signal sequence and $1 \le m \le N_{RB}^{max,UL}$. Multiple reference signal sequences are defined from a single base sequence through different values of α. Base sequences $\bar{r}_{u,v}(n)$ are divided into groups, where $u \in \{0,1,...,29\}$ is the group number and v is the base sequence number within the group, such that each group contains one base sequence ($v = 0$) of each length $M_{sc}^{RS} = mN_{sc}^{RB}$, $1 \le m \le 5$ and two base sequences ($v = 0,1$) of each length $M_{sc}^{RS} = mN_{sc}^{RB}$, $6 \le m \le N_{RB}^{max,UL}$. The sequence group number u and the number v within the group may vary in time as described in Sections 5.5.1.3 and 5.5.1.4, respectively. The definition of the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{sc}^{RS}-1)$ depends on the sequence length M_{sc}^{RS}. See e.g., 3GPP TS 36.211 V8.9.0 at pg. 21.

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U.S. Patent No. 10,771,302: Claim 23(c)

"a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:"

5.5.3 Sounding reference signal

5.5.3.1 Sequence generation

The sounding reference signal sequence $r^{\text{SRS}}(n) = r_{u,v}^{(\alpha)}(n)$ is defined by Section 5.5.1, where u is the PUCCH sequence-group number defined in Section 5.5.1.3 and v is the base sequence number defined in Section 5.5.1.4. The cyclic shift α of the sounding reference signal is given as

$$\alpha = 2\pi \frac{n_{\text{SRS}}^{\text{cs}}}{8},$$

where $n_{\text{SRS}}^{\text{cs}}$ is configured for each UE by higher layers and $n_{\text{SRS}}^{\text{cs}} = 0, 1, 2, 3, 4, 5, 6, 7$.

5.5.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in Section 5.1.3.1 in [4], and mapped in sequence starting with $r^{\text{SRS}}(0)$ to resource elements (k, l) according to

$$a_{2k+k_0,l} = \begin{cases} \beta_{\text{SRS}} r^{\text{SRS}}(k) & k = 0,1,\ldots,M_{\text{sc},b}^{\text{RS}} - 1 \\ 0 & \text{otherwise} \end{cases}$$

where k_0 is the frequency-domain starting position of the sounding reference signal and for $b = B_{SRS}$ $M_{\text{sc},b}^{\text{RS}}$ is the length of the sounding reference signal sequence defined as

$$M_{\text{sc},b}^{\text{RS}} = m_{\text{SRS},b} N_{\text{sc}}^{\text{RB}} / 2$$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 28.

The UE transmits the SRS to the eNodeB.

5.5.3.3 Sounding reference signal subframe configuration

The cell specific subframe configuration period T_{SFC} and the cell specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2, for FDD and TDD, respectively. Sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{SFC} \in \Delta_{SFC}$. For TDD, sounding reference signal is transmitted only in configured UL subframes or UpPTS.

U.S. Patent No. 10,771,302: Claim 23(c)

"a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:"

	See e.g., 3GPP TS 36.211 V8.9.0 at pg. 31.

U.S. Patent No. 10,771,302: Claim 23(d)

" the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and"

the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and	The probing signal transmitted by Honda's Accused Products is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system. *E.g.*, For example, the SRS is mapped to one symbol in the time domain but over many subcarriers in the frequency domain, and overlaps with PUCCH in the time domain. **5.5.3 Sounding reference signal** **5.5.3.1 Sequence generation** The sounding reference signal sequence $r^{\text{SRS}}(n) = r_{u,v}^{(\alpha)}(n)$ is defined by Section 5.5.1, where u is the PUCCH sequence-group number defined in Section 5.5.1.3 and v is the base sequence number defined in Section 5.5.1.4. The cyclic shift α of the sounding reference signal is given as $$\alpha = 2\pi \frac{n_{\text{SRS}}^{\text{cs}}}{8},$$ where $n_{\text{SRS}}^{\text{cs}}$ is configured for each UE by higher layers and $n_{\text{SRS}}^{\text{cs}} = 0, 1, 2, 3, 4, 5, 6, 7$. **5.5.3.2 Mapping to physical resources** The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in Section 5.1.3.1 in [4], and mapped in sequence starting with $r^{\text{SRS}}(0)$ to resource elements (k, l) according to $$a_{2k+k_0,l} = \begin{cases} \beta_{\text{SRS}} r^{\text{SRS}}(k) & k = 0,1,\ldots,M_{\text{sc},b}^{\text{RS}} - 1 \\ 0 & \text{otherwise} \end{cases}$$ where k_0 is the frequency-domain starting position of the sounding reference signal and for $b = B_{SRS}$ $M_{\text{sc},b}^{\text{RS}}$ is the length of the sounding reference signal sequence defined as $$M_{\text{sc},b}^{\text{RS}} = m_{\text{SRS},b} N_{\text{sc}}^{\text{RB}} / 2$$ See e.g., 3GPP TS 36.211 V8.9.0 at pg. 28.

U.S. Patent No. 10,771,302: Claim 23(d)

" the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and"

The UE transmits the SRS to the eNodeB.

5.5.3.3 Sounding reference signal subframe configuration

The cell specific subframe configuration period T_{SFC} and the cell specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2, for FDD and TDD, respectively. Sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{SFC} \in \Delta_{SFC}$. For TDD, sounding reference signal is transmitted only in configured UL subframes or UpPTS.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 31.

In case of simultaneous transmission of sounding reference signal and PUCCH format 1, 1a or 1b, one SC-FDMA symbol on PUCCH shall punctured.

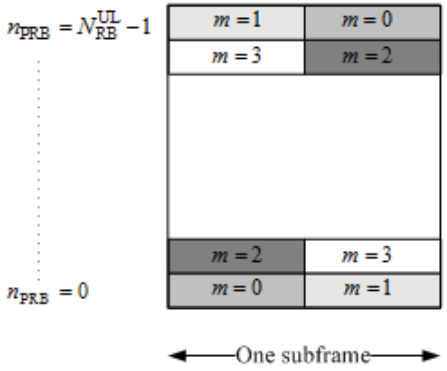


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 21.

For all subframes other than special subframes, the sounding reference signal shall be transmitted in the last symbol of the subframe.

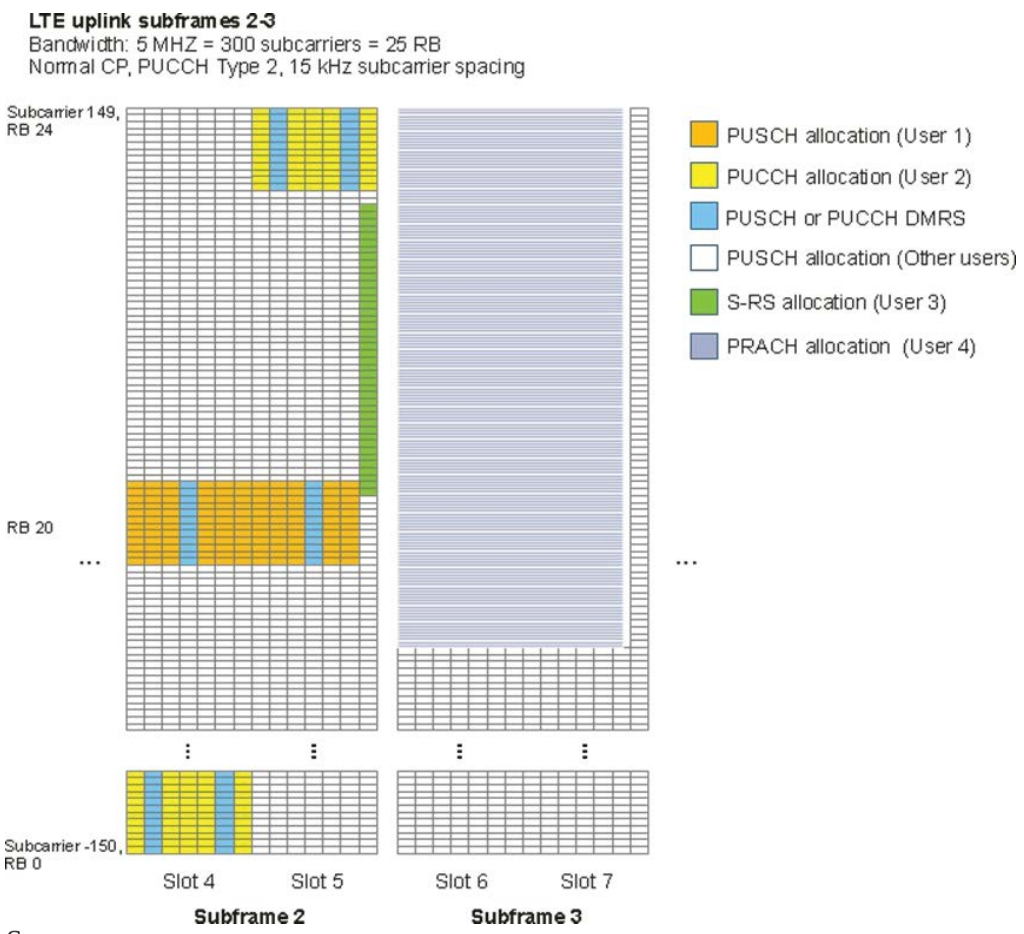
See e.g., 3GPP TS 36.211 V8.9.0 at pg. 30.

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U.S. Patent No. 10,771,302: Claim 23(d)

" the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and"

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See e.g., http://rfmw.em.keysight.com/wireless/helpfiles/89600b/webhelp/subsystems/lte/content/lte_overview.htm

U.S. Patent No. 10,771,302: Claim 23(e)

" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.	The probing signal transmitted by Honda's Accused Products is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.. *E.g.*, For example, SRS transmissions are sent using a portion of the uplink bandwidth. **8.2 UE sounding procedure** The following Sounding Reference Symbol (SRS) parameters are UE specific semi-statically configurable by higher layers: • Transmission comb k_{TC}, as defined in Section 5.5.3.2 of [3] • Starting physical resource block assignment n_{RRC}, as defined in Section 5.5.3.2 of [3] • Duration of SRS transmission: single or indefinite (until disabled), as defined in [11] • SRS configuration index I_{SRS} for SRS periodicity and SRS subframe offset T_{offset}, as defined in Table 8.2-1 and Table 8.2-2 • SRS bandwidth B_{SRS}, as defined in Section 5.5.3.2 of [3] • Frequency hopping bandwidth, b_{hop}, as defined in Section 5.5.3.2 of [3] • Cyclic shift n_{SRS}^{cs}, as defined in Section 5.5.3.2 of [3] The cell specific SRS transmission bandwidths C_{SRS} are configured by higher layers. The allowable values are given in Section 5.5.3.2 of [3]. See e.g., 3GPP TS 36.213 V8.8.0 at pg. 55. SRS does not overlap in the frequency domain with PUCCH subcarriers.

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U.S. Patent No. 10,771,302: Claim 23(e)

" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

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15.6.3.1 SRS Bandwidths

Some of the factors which affect the SRS bandwidth are the maximum power of the UE, the number of supportable sounding UEs, and the sounding bandwidth needed to benefit from uplink channel-dependent scheduling. Full bandwidth sounding provides the most complete channel information when the UE is sufficiently close to the eNodeB, but degrades as the path-loss increases when the UE cannot further increase its transmit power to maintain the transmission across the full bandwidth. Full bandwidth transmission of SRS also limits the number of simultaneous UEs whose channels can be sounded, due to the limited number of cyclic time shifts (eight cyclic time shifts per SRS comb as explained above).

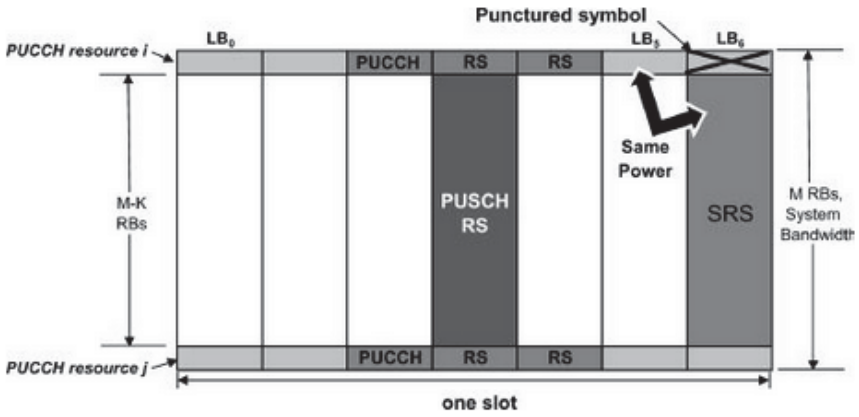
To improve the SNR and support a larger number of SRSs, up to four SRS bandwidths can be simultaneously supported in LTE depending on the system bandwidth. To provide flexibility with the values for the SRS bandwidths, eight sets of four SRS bandwidths are defined for each possible system bandwidth. RRC signalling indicates which of the eight sets is applicable in the cell by means of a 3-bit cell-specific parameter 'srs-BandwidthConfig'. This allows some variability in the maximum SRS bandwidths, which is important as the SRS region does not include the PUCCH region near the edges of the system bandwidth (see Section 16.3), which is itself variable in bandwidth. An example of the eight sets of four SRS bandwidths applicable to uplink system bandwidths in the range 40–60 RBs is shown in Table 15.1 (see [4, Table 5.5.3.2–2]).

See Sesia, Toufik and Baker, "LTE: The UMTS Long Term Evolution From Theory to Practice", at p. 338.

Figure 16.13: A UE may not simultaneously transmit on SRS and PUCCH or PUSCH, in order to avoid violating the single-carrier nature of the signal. Therefore, a PUCCH or PUSCH symbol may be punctured if SRS is transmitted.

U.S. Patent No. 10,771,302: Claim 23(e)

" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

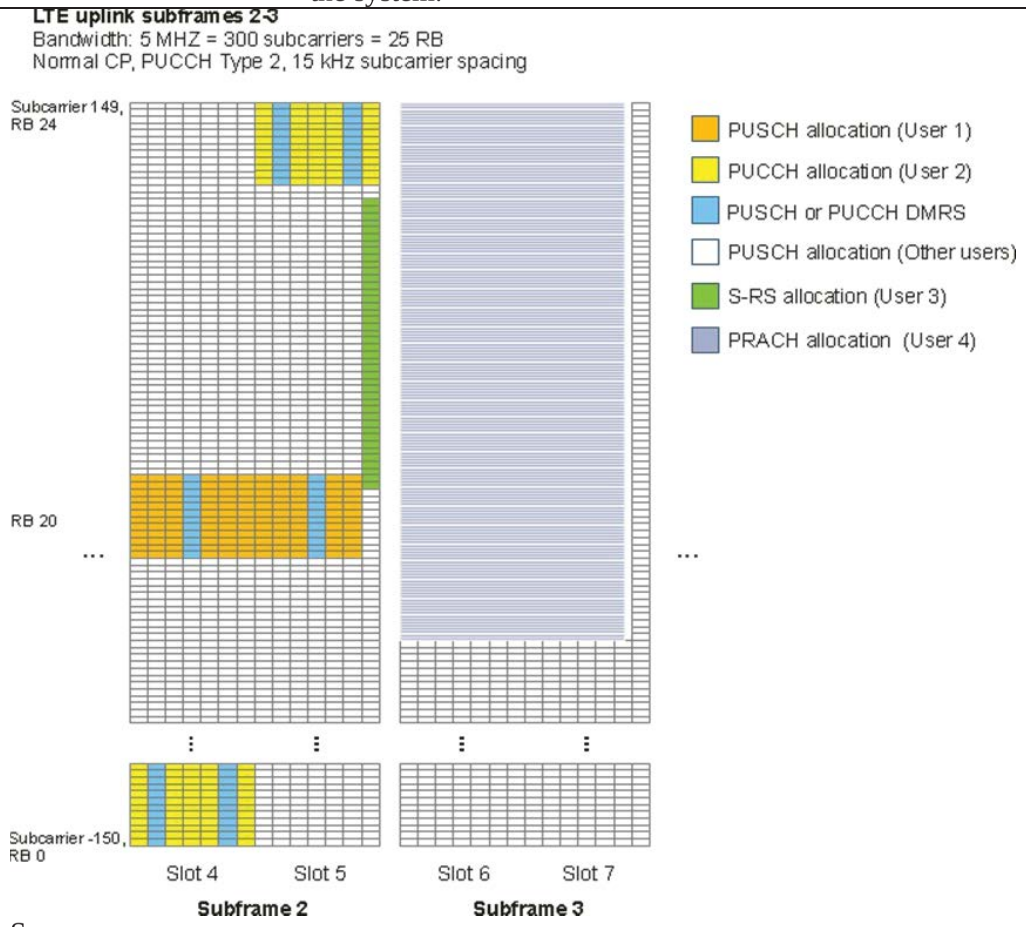
	 See e.g., Sesia, Toufik and Baker, “LTE: The UMTS Long Term Evolution From Theory to Practice”, at p. 358.

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U.S. Patent No. 10,771,302: Claim 23(e)

" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

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See e.g., http://rfmw.em.keysight.com/wireless/helpfiles/89600b/webhelp/subsystems/lte/content/lte_overview.htm

For example, the PUCCH is mapped into a resource block a single resource block in each time slot that is located near the top or the bottom of the uplink bandwidth.

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" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

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5.4.3 Mapping to physical resources

The block of complex-valued symbols $z(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Section 5.1.2.1 in [4], and mapped in sequence starting with $z(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z(i)$ to resource elements (k,l) not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe.

The physical resource blocks to be used for transmission of PUCCH in slot n_s is given by

$$n_{\text{PRB}} = \begin{cases} \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m+n_s \bmod 2) \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 1 - \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m+n_s \bmod 2) \bmod 2 = 1 \end{cases}$$

where the variable m depends on the PUCCH format. For formats 1, 1a and 1b

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" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

$$m = \begin{cases} N_{RB}^{(2)} & \text{if } n_{PUCCH}^{(1)} < c \cdot N_{cs}^{(1)} / \Delta_{shift}^{PUCCH} \\ \left\lfloor \dfrac{n_{PUCCH}^{(1)} - c \cdot N_{cs}^{(1)} / \Delta_{shift}^{PUCCH}}{c \cdot N_{sc}^{RB} / \Delta_{shift}^{PUCCH}} \right\rfloor + N_{RB}^{(2)} + \left\lceil \dfrac{N_{cs}^{(1)}}{8} \right\rceil & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and for formats 2, 2a and 2b

$$m = \left\lfloor n_{PUCCH}^{(2)} / N_{sc}^{RB} \right\rfloor$$

Mapping of modulation symbols for the physical uplink control channel is illustrated in Figure 5.4.3-1.

In case of simultaneous transmission of sounding reference signal and PUCCH format 1, 1a or 1b, one SC-FDMA symbol on PUCCH shall punctured.

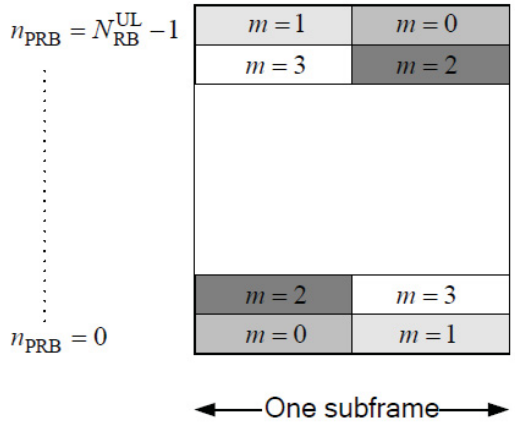


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH.

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 20-21.

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U.S. Patent No. 10,771,302: Claim 23(e)

" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

	The SRS signal may be mapped to a variety of locations in the frequency domain depending on the configuration of the system. Tables 5.5.3.2-1 through 5.5.3.2-4 provide the available LTE configurations. These configurations map the SRS in blocks towards the middle of uplink bandwidth and avoid the resource blocks at the ends of the uplink bandwidth that carry the PUCCH. 5.5.3.2 Mapping to physical resources The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in Section 5.1.3.1 in [4], and mapped in sequence starting with $r^{\text{SRS}}(0)$ to resource elements (k,l) according to $a_{2k+k_0,l} = \begin{cases} \beta_{\text{SRS}} r^{\text{SRS}}(k) & k = 0,1,\ldots,M_{\text{sc},b}^{\text{RS}}-1 \\ 0 & \text{otherwise} \end{cases}$

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" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

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where k_0 is the frequency-domain starting position of the sounding reference signal and for $b = B_{SRS}$ $M_{sc,b}^{RS}$ is the length of the sounding reference signal sequence defined as

$$M_{sc,b}^{RS} = m_{SRS,b} N_{sc}^{RB} / 2$$

where $m_{SRS,b}$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth N_{RB}^{UL}. The cell-specific parameter *srs-BandwidthConfig* $C_{SRS} \in \{0,1,2,3,4,5,6,7\}$ and the UE-specific parameter *srs-Bandwidth* $B_{SRS} \in \{0,1,2,3\}$ are given by higher layers. For UpPTS, $m_{SRS,0}$ shall be reconfigured to $m_{SRS,0}^{max} = \max_{c \in C} \{m_{SRS,0}^{c}\} \leq \left(N_{RB}^{UL} - 6N_{RA}\right)$ if this reconfiguration is enabled by the cell specific parameter *srsMaxUpPts* given by higher layers, otherwise if the reconfiguration is disabled $m_{SRS,0}^{max} = m_{SRS,0}$, where c is a SRS BW configuration and C_{SRS} is the set of SRS BW configurations from the Tables 5.5.3.2-1 to 5.5.3.2-4 for each uplink bandwidth N_{RB}^{UL}, N_{RA} is the number of format 4 PRACH in the addressed UpPTS and derived from Table 5.7.1-4.

The frequency-domain starting position k_0 is defined by

$$k_0 = k_0' + \sum_{b=0}^{B_{SRS}} 2 M_{sc,b}^{RS} n_b$$

where for normal uplink subframes $k_0' = \left(\lfloor N_{RB}^{UL} / 2 \rfloor - m_{SRS,0}/2\right) N_{SC}^{RB} + k_{TC}$, for UpPTS k_0' is defined by:

$$k_0' = \begin{cases} (N_{RB}^{UL} - m_{SRS,0}^{max}) N_{sc}^{RB} + k_{TC} & \text{if } \left((n_f \bmod 2) \times (2 - N_{SP}) + n_{hf}\right) \bmod 2 = 0 \\ k_{TC} & \text{otherwise} \end{cases}$$

$k_{TC} \in \{0,1\}$ is the parameter *transmissionComb* provided by higher layers for the UE, and n_b is frequency position index. n_{hf} is equal to 0 for UpPTS in first half frame, and equal to 1 for UpPTS in second half frame.

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" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

Table 5.5.3.2-1: $m_{SRS,b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $6 \le N_{RB}^{UL} \le 40$.

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{SRS} = 0$		SRS-Bandwidth $B_{SRS} = 1$		SRS-Bandwidth $B_{SRS} = 2$		SRS-Bandwidth $B_{SRS} = 3$	
	$m_{SRS,0}$	N_0	$m_{SRS,1}$	N_1	$m_{SRS,2}$	N_2	$m_{SRS,3}$	N_3
0	36	1	12	3	4	3	4	1
1	32	1	16	2	8	2	4	2
2	24	1	4	6	4	1	4	1
3	20	1	4	5	4	1	4	1
4	16	1	4	4	4	1	4	1
5	12	1	4	3	4	1	4	1
6	8	1	4	2	4	1	4	1
7	4	1	4	1	4	1	4	1

Table 5.5.3.2-2: $m_{SRS,b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $40 < N_{RB}^{UL} \le 60$.

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{SRS} = 0$		SRS-Bandwidth $B_{SRS} = 1$		SRS-Bandwidth $B_{SRS} = 2$		SRS-Bandwidth $B_{SRS} = 3$	
	$m_{SRS,0}$	N_0	$m_{SRS,1}$	N_1	$m_{SRS,2}$	N_2	$m_{SRS,3}$	N_3
0	48	1	24	2	12	2	4	3
1	48	1	16	3	8	2	4	2
2	40	1	20	2	4	5	4	1
3	36	1	12	3	4	3	4	1
4	32	1	16	2	8	2	4	2
5	24	1	4	6	4	1	4	1
6	20	1	4	5	4	1	4	1
7	16	1	4	4	4	1	4	1

Table 5.5.3.2-3: $m_{SRS,b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $60 < N_{RB}^{UL} \le 80$.

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{SRS} = 0$		SRS-Bandwidth $B_{SRS} = 1$		SRS-Bandwidth $B_{SRS} = 2$		SRS-Bandwidth $B_{SRS} = 3$	
	$m_{SRS,0}$	N_0	$m_{SRS,1}$	N_1	$m_{SRS,2}$	N_2	$m_{SRS,3}$	N_3
0	72	1	24	3	12	2	4	3
1	64	1	32	2	16	2	4	4
2	60	1	20	3	4	5	4	1
3	48	1	24	2	12	2	4	3
4	48	1	16	3	8	2	4	2
5	40	1	20	2	4	5	4	1
6	36	1	12	3	4	3	4	1
7	32	1	16	2	8	2	4	2

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" the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system."

Table 5.5.3.2-4: $m_{\mathrm{SRS},b}$ **and** N_b, $b = 0,1,2,3$, **values for the uplink bandwidth of** $80 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 110$.

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{\mathrm{SRS}} = 0$		SRS-Bandwidth $B_{\mathrm{SRS}} = 1$		SRS-Bandwidth $B_{\mathrm{SRS}} = 2$		SRS-Bandwidth $B_{\mathrm{SRS}} = 3$	
	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	96	1	48	2	24	2	4	6
1	96	1	32	3	16	2	4	4
2	80	1	40	2	20	2	4	5
3	72	1	24	3	12	2	4	3
4	64	1	32	2	16	2	4	4
5	60	1	20	3	4	5	4	1
6	48	1	24	2	12	2	4	3
7	48	1	16	3	8	2	4	2

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 28-31.

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JS 44 (Rev. 04/21)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. *(SEE INSTRUCTIONS ON NEXT PAGE OF THIS FORM.)*

I. (a) PLAINTIFFS

NEO WIRELESS, LLC

(b) County of Residence of First Listed Plaintiff Delaware County, PA
(EXCEPT IN U.S. PLAINTIFF CASES)

(c) Attorneys *(Firm Name, Address, and Telephone Number)*

Sand, Sebolt & Wernow Co., LPA
4940 Munson St. NW - Suite 1100, Canton, Ohio 44718

DEFENDANTS

AMERICAN HONDA MOTOR CO., INC. & HONDA DEVELOPMENT, et al.

County of Residence of First Listed Defendant _____
(IN U.S. PLAINTIFF CASES ONLY)

NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE TRACT OF LAND INVOLVED.

Attorneys *(If Known)*

II. BASIS OF JURISDICTION *(Place an "X" in One Box Only)*

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question *(U.S. Government Not a Party)*
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity *(Indicate Citizenship of Parties in Item III)*

III. CITIZENSHIP OF PRINCIPAL PARTIES *(Place an "X" in One Box for Plaintiff and One Box for Defendant)*

(For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated *or* Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated *and* Principal Place of Business In Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. NATURE OF SUIT *(Place an "X" in One Box Only)*

Click here for: Nature of Suit Code Descriptions.

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loans (Excludes Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability
- ☐ 196 Franchise

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury
- ☐ 362 Personal Injury - Medical Malpractice

PERSONAL INJURY
- ☐ 365 Personal Injury - Product Liability
- ☐ 367 Health Care/ Pharmaceutical Personal Injury Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 440 Other Civil Rights
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 445 Amer. w/Disabilities - Employment
- ☐ 446 Amer. w/Disabilities - Other
- ☐ 448 Education

PRISONER PETITIONS

Habeas Corpus:
- ☐ 463 Alien Detainee
- ☐ 510 Motions to Vacate Sentence
- ☐ 530 General
- ☐ 535 Death Penalty

Other:
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition
- ☐ 560 Civil Detainee - Conditions of Confinement

FORFEITURE/PENALTY
- ☐ 625 Drug Related Seizure of Property 21 USC 881
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Management Relations
- ☐ 740 Railway Labor Act
- ☐ 751 Family and Medical Leave Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Employee Retirement Income Security Act

IMMIGRATION
- ☐ 462 Naturalization Application
- ☐ 465 Other Immigration Actions

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

INTELLECTUAL PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 835 Patent - Abbreviated New Drug Application
- ☐ 840 Trademark
- ☐ 880 Defend Trade Secrets Act of 2016

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS—Third Party 26 USC 7609

OTHER STATUTES
- ☐ 375 False Claims Act
- ☐ 376 Qui Tam (31 USC 3729(a))
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 480 Consumer Credit (15 USC 1681 or 1692)
- ☐ 485 Telephone Consumer Protection Act
- ☐ 490 Cable/Sat TV
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 890 Other Statutory Actions
- ☐ 891 Agricultural Acts
- ☐ 893 Environmental Matters
- ☐ 895 Freedom of Information Act
- ☐ 896 Arbitration
- ☐ 899 Administrative Procedure Act/Review or Appeal of Agency Decision
- ☐ 950 Constitutionality of State Statutes

V. ORIGIN *(Place an "X" in One Box Only)*

☒ 1 Original Proceeding ☐ 2 Removed from State Court ☐ 3 Remanded from Appellate Court ☐ 4 Reinstated or Reopened ☐ 5 Transferred from Another District *(specify)* ☐ 6 Multidistrict Litigation - Transfer ☐ 8 Multidistrict Litigation - Direct File

VI. CAUSE OF ACTION

Cite the U.S. Civil Statute under which you are filing ***(Do not cite jurisdictional statutes unless diversity)***:
35 U.S.C. §§ 1, et seq.

Brief description of cause:
Patent Infringement

VII. REQUESTED IN COMPLAINT:

☐ CHECK IF THIS IS A **CLASS ACTION** UNDER RULE 23, F.R.Cv.P.

DEMAND $

CHECK YES only if demanded in complaint:
JURY DEMAND: ☒ Yes ☐ No

VIII. RELATED CASE(S) IF ANY

(See instructions): JUDGE _____ DOCKET NUMBER _____

DATE
Mar 29, 2022

SIGNATURE OF ATTORNEY OF RECORD
/s/ Howard L. Wernow

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS 44

Authority For Civil Cover Sheet

The JS 44 civil cover sheet and the information contained herein neither replaces nor supplements the filings and service of pleading or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. Consequently, a civil cover sheet is submitted to the Clerk of Court for each civil complaint filed. The attorney filing a case should complete the form as follows:

I.(a) Plaintiffs-Defendants. Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.

(b) County of Residence. For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved.)

(c) Attorneys. Enter the firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)".

II. Jurisdiction. The basis of jurisdiction is set forth under Rule 8(a), F.R.Cv.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.
United States plaintiff. (1) Jurisdiction based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here.
United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.
Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.
Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked. (See Section III below**; NOTE: federal question actions take precedence over diversity cases.**)

III. Residence (citizenship) of Principal Parties. This section of the JS 44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.

IV. Nature of Suit. Place an "X" in the appropriate box. If there are multiple nature of suit codes associated with the case, pick the nature of suit code that is most applicable. Click here for: Nature of Suit Code Descriptions.

V. Origin. Place an "X" in one of the seven boxes.
Original Proceedings. (1) Cases which originate in the United States district courts.
Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C., Section 1441.
Remanded from Appellate Court. (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.
Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.
Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.
Multidistrict Litigation – Transfer. (6) Check this box when a multidistrict case is transferred into the district under authority of Title 28 U.S.C. Section 1407.
Multidistrict Litigation – Direct File. (8) Check this box when a multidistrict case is filed in the same district as the Master MDL docket.
PLEASE NOTE THAT THERE IS NOT AN ORIGIN CODE 7. Origin Code 7 was used for historical records and is no longer relevant due to changes in statute.

VI. Cause of Action. Report the civil statute directly related to the cause of action and give a brief description of the cause. **Do not cite jurisdictional statutes unless diversity.** Example: U.S. Civil Statute: 47 USC 553 Brief Description: Unauthorized reception of cable service.

VII. Requested in Complaint. Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.
Demand. In this space enter the actual dollar amount being demanded or indicate other demand, such as a preliminary injunction.
Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.

VIII. Related Cases. This section of the JS 44 is used to reference related pending cases, if any. If there are related pending cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

AO 440 (Rev. 06/12) Summons in a Civil Action

UNITED STATES DISTRICT COURT

for the

Southern District of Ohio

NEO WIRELESS, LLC *Plaintiff(s)*	)	
v.	)	Civil Action No.
AMERICAN HONDA MOTOR CO., INC. & HONDA DEVELOPMENT, et al. *Defendant(s)*	)	

SUMMONS IN A CIVIL ACTION

To: *(Defendant's name and address)* American Honda Motor Co., Inc.
c/o Corporation Service Company
50 West Broad Street - Suite 1330
Columbus, Ohio 43215

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it) — or 60 days if you are the United States or a United States agency, or an officer or employee of the United States described in Fed. R. Civ. P. 12 (a)(2) or (3) — you must serve on the plaintiff an answer to the attached complaint or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff or plaintiff's attorney, whose name and address are: Howard L. Wernow
Sand, Sebolt & Wernow Co., LPA
Aegis Tower - Suite 1100
4940 Munson Street NW
Canton, Ohio 44718

If you fail to respond, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

CLERK OF COURT

Date: _____

_____
Signature of Clerk or Deputy Clerk

Civil Action No.

PROOF OF SERVICE

(This section should not be filed with the court unless required by Fed. R. Civ. P. 4 (l))

This summons for *(name of individual and title, if any)* _____ was received by me on *(date)* _____ .

❒ I personally served the summons on the individual at *(place)* _____ on *(date)* _____ ; or

❒ I left the summons at the individual's residence or usual place of abode with *(name)* _____ , a person of suitable age and discretion who resides there, on *(date)* _____ , and mailed a copy to the individual's last known address; or

❒ I served the summons on *(name of individual)* _____ , who is designated by law to accept service of process on behalf of *(name of organization)* _____ on *(date)* _____ ; or

❒ I returned the summons unexecuted because _____ ; or

❒ Other *(specify):*

My fees are $ _____ for travel and $ _____ for services, for a total of $ 0.00 .

I declare under penalty of perjury that this information is true.

Date: _____

_____
Server's signature

_____
Printed name and title

_____
Server's address

Additional information regarding attempted service, etc:

AO 440 (Rev. 06/12) Summons in a Civil Action

UNITED STATES DISTRICT COURT

for the

Southern District of Ohio

NEO WIRELESS, LLC *Plaintiff(s)*	)	
v.	)	Civil Action No.
AMERICAN HONDA MOTOR CO., INC. & HONDA DEVELOPMENT, et al. *Defendant(s)*	)	

SUMMONS IN A CIVIL ACTION

To: *(Defendant's name and address)* Honda Development & Manufacturing of America, LLC
c/o Corporation Service Company
50 West Broad Street - Suite 1330
Columbus, Ohio 43215

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it) — or 60 days if you are the United States or a United States agency, or an officer or employee of the United States described in Fed. R. Civ. P. 12 (a)(2) or (3) — you must serve on the plaintiff an answer to the attached complaint or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff or plaintiff's attorney, whose name and address are: Howard L. Wernow
Sand, Sebolt & Wernow Co., LPA
Aegis Tower - Suite 1100
4940 Munson Street NW
Canton, Ohio 44718

If you fail to respond, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

CLERK OF COURT

Date: _____

_____
Signature of Clerk or Deputy Clerk

Civil Action No.

PROOF OF SERVICE

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❒ I personally served the summons on the individual at *(place)* _____ on *(date)* _____ ; or

❒ I left the summons at the individual's residence or usual place of abode with *(name)* _____ , a person of suitable age and discretion who resides there, on *(date)* _____ , and mailed a copy to the individual's last known address; or

❒ I served the summons on *(name of individual)* _____ , who is designated by law to accept service of process on behalf of *(name of organization)* _____ on *(date)* _____ ; or

❒ I returned the summons unexecuted because _____ ; or

❒ Other *(specify):*

My fees are $ _____ for travel and $ _____ for services, for a total of $ 0.00 .

I declare under penalty of perjury that this information is true.

Date: _____

_____
Server's signature

_____
Printed name and title

_____
Server's address

Additional information regarding attempted service, etc: