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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	9147-99460-US
First Inventor	Paul Howard
Title	Feedback Control in an FDD TDD-CDMA
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☐ **Fee Transmittal Form** (e.g., PTO/SB/17)
2. ☐ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 19]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 5]
5. **Oath or Declaration** [*Total Sheets* 1]
   a. ☐ Newly executed (original or copy)
   b. ☑ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☑ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ADDRESS TO: **Commissioner for Patents**
P.O. Box 1450
Alexandria VA 22313-1450

ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee_____
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (*Should be specifically itemized)*
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☑ Other: General Authorization for Petition for Extension of Time

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☑ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: 11/646,692

Prior application information: *Examiner* Ronald B. Abelson *Art Unit:* 2476

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 22242 ***OR*** ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Email	

Signature	/Steven G. Parmelee/	Date	2011-07-05
Name (Print/Type)	Steven G. Parmelee	Registration No. (Attorney/Agent)	28,790

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First Named Inventor:	Paul Howard
Filed:	Herewith
Title:	FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM
Attorney Docket:	9147-99460-US
Customer No.:	22242

This Authorization was electronically filed on April 21, 2011 using the USPTO's EFS-Web.

GENERAL AUTHORIZATION FOR PETITION FOR EXTENSION OF TIME UNDER 37 C.F.R. § 1.136(a)(3)

Commissioner for Patents
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Sir:

Applicant(s) hereby request under 37 C.F.R. §1.136(a)(3) by this general authorization that any concurrent or future reply submitted by Applicant(s) to the United States Patent and Trademark Office for the above-identified patent application requiring a petition for an extension of time under §1.136(a) for its timely submission be treated as incorporating therein a petition for an extension of time for the appropriate length of time.

If Applicant(s) do not timely pay for any extension fee(s) pursuant to 37 C.F.R. §1.136(a) which may become due for this application under 37 C.F.R. §1.17, the Commissioner is hereby authorized to charge such fee(s), and any additional fees which may be required in this application under 37 C.F.R. §§1.16-1.17 during its entire pendency, or credit any overpayment, to Deposit Account No. 06-1135.

Date: July 5, 2011

Steven G. Parmelee
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1 Remove

Applicant Authority ◉ Inventor ○ Legal Representative under 35 U.S.C. 117 ○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Paul		Howard	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Briston	Country Of Residence[i]	UK

Citizenship under 37 CFR 1.41(b)[i] UK

Mailing Address of Applicant:

Address 1	Tennyson Cottage, Tennyson Road		
Address 2	Horfield		
City	Bristol	State/Province	
Postal Code	BS7 8SB	Country[i]	UK

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

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For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	22242		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	Feedback Control in an FDD TDD-CDMA System		
Attorney Docket Number	9147-99460-US	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	5	Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

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Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	22242		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation of	11646692	2006-12-27

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

Remove

Application Number	Country [i]	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			○ Yes ◉ No

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Assignee Information:

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Assignee 1 Remove

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

If the Assignee is an Organization check here. ☒			
Organization Name	Wireless Technology Solutions LLC		
Mailing Address Information:			
Address 1	550 Madison Avenue		
Address 2			
City	New York	**State/Province**	NY
Country [i]	US	Postal Code	10022
Phone Number		Fax Number	
Email Address			
Additional Assignee Data may be generated within this form by selecting the **Add** button.		Add	

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/Steven G. Parmelee/			Date (YYYY-MM-DD)	2011-07-05
First Name	Steven G.	Last Name	Parmelee	Registration Number	28790

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

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FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM

BACKGROUND OF THE INVENTION

[0001] Time division-code division multiple access (TD-CDMA) is an air interface technology that combines the benefits of the three elemental concepts in a universal mobile telecommunication system (UMTS): time division multiple access (TDMA); code division multiple access (CDMA); and time division duplex (TDD). TDD, in particular, uses the same radio channel for both uplink and downlink communications, and discriminates between signals by separating the transmissions in time. One of the benefits obtained by operating both links on the same frequency is the ability to exploit channel reciprocity.

[0002] Channel reciprocity gives equipment the ability to derive information about uplink channel conditions from downlink channel conditions based upon signals received by the user equipment (UE). Pathloss is one example of channel information that can be obtained from channel reciprocity. Knowledge of the uplink pathloss enables open-loop power control to be employed for uplink transmissions. For example, uplink power control is important for the operation of the CDMA element of TD-CDMA as it counteracts the near-far effect that would otherwise be encountered if all UEs transmitted at a fixed power regardless of the uplink pathloss.

[0003] The open-loop uplink power control feature provides a significant advantage when coupled with a multiple access data transmission system that is used for packet-based communication and/or shared channels. When access to a limited number of uplink channels is shared between a large population of terminals it is imperative that access to the channels can be switched between terminals with minimal latency. A data terminal that can derive information needed to access uplink channels from the downlink transmissions (beacon signals) has a significant advantage over a terminal that relies on the (lengthy) configuration of a dedicated channel in order to establish a feedback channel.

[0004] However, channel reciprocity cannot always be guaranteed. For example TDD transmissions may not be permitted in certain frequency spectrum allocations; this is a regulatory issue and may be used to protect other wireless equipment in the same or adjacent frequency bands.

In these situations the correlation between uplink and downlink channels is lost because the channels are transported on carrier frequencies that are separated in frequency by an amount that is greater than the coherence bandwidth of the channel (usually, only a few MHz separation is sufficient to cause the uplink and downlink fading profiles to be independent).

[0005] In high speed mobile applications, the time delay between downlink and uplink transmissions may exceed the coherence time of the channel. The maximum time delay that can be tolerated is a function of the mobile speed and the RF carrier frequency used, with the coherence time reducing with increasing speed and RF carrier frequency. Also, the use of multiple transmit and/or receive antennas at the network and/or the mobile terminal can introduce unintentional decorrelation between the uplink and downlink channels.

[0006] If the TD-CDMA air interface is to be used in applications where the correlation between the uplink and downlink path loss is not guaranteed, then it would be advantageous to find a substitute for channel reciprocity.

BRIEF SUMMARY OF THE INVENTION

[0007] Although it is desirable to support air interfaces where the pathloss is not reciprocal, known conventional methods do not deal directly with the evolution or adaptation of an air interface that uses channel reciprocity to deliver key features and advantages where channel reciprocity is not guaranteed. The adaptation provided in embodiments of the invention introduces a new technique for uplink channel control that uses a feedback scheme as a substitute for the absence of channel reciprocity, with minimal impact on the ability of the air interface to support uplink shared channels.

[0008] Embodiments of the present invention enable active feedback control between a base station and user equipment (UE). In particular, the operation of a system designed for TDD, or unpaired operation, is expanded to operate in FDD, or paired, mode. For example, an uplink beacon function (for power control) and a modified random access process substitute for the information lost due to the lack of channel reciprocity in paired operation. Embodiments of the invention allow a terminal to transmit the uplink physical channel control signal (UL_Beacon) independently from the uplink physical channel. Therefore, the implementation of closed loop feedback may operate in

the absence of an uplink physical channel. In one embodiment, a UE allocates a time slot for a beacon signal separated from the time slots for data in a frame. A second time slot is allocated within the frame for the base station to transmit a control signal in response to the beacon signal. The control signal instructs the UE to adjust a transmission parameter.

[0009] A UL_Beacon signal may be combined with a physical layer common control channel (PLCCH) to form a feedback system. A dedicated timeslot groups all of the UL_Beacon signals from multiple UEs in a specific uplink timeslot. By grouping the UL_Beacon signals together, embodiments obtain separation between the UL_Beacon signals and the standard uplink physical channels. Additionally, in a synchronous system embodiments of the invention detect and cancel the UL_Beacon signals from other cell sites (inter-cell interference). The PLCCH carries feedback information to the UEs that are transmitting UL_Beacon signals. The PLCCH can share a timeslot with other physical channels by exploiting the CDMA aspect of the system.

[0010] In other embodiments, the number of supported UEs can be increased by fractionating the use of the UL_Beacon and PLCCH across a multiframe period. Fractionation may also prevent timeslot blocking where half duplex UEs have a long UL/DL switching time. Additionally, support for half duplex terminals is implicit due to the nature of the TDMA frame structure. The system may manage the allocation of resource across the population of terminals such that the full capacity of the base station can be utilized even when only half-duplex terminals are deployed. In embodiments of the invention, full-duplex terminals can be still be supported along with half duplex UEs.

[0011] Moreover, in other embodiments, a radio resource control (RRC) connected state covers the subset of terminals that are in cell forward access channel (Cell_FACH), which are also transmitting UL_Beacon and receiving PLCCH, thus creating an active control feedback channel. Management of the UEs that are in Cell_Active state may remove users that are less active, and may add users that are newly active while retaining users that may have on-going data transfer requirements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 illustrates a cellular communication system according to embodiments of the invention;

[0013] Figure 2 illustrates a timeslot arrangement for uplink and downlink messages supporting the UL_Beacon and its corresponding PLCCH within a TD-CDMA frame structure modified to support FDD according to embodiments of the invention;

[0014] Figure 3 illustrates fractionation in different frames at the base station according to embodiments of the invention;

[0015] Figure 4 illustrates UTRA RRC connected modes according to embodiments of the invention;

[0016] Figure 5 illustrates a computer system that may be employed to implement embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Figure 1 illustrates an example of a cellular communication system according to embodiments of the invention. The network includes a user equipment (UE) domain, a radio access network (RAN) domain, and a core network domain. The UE domain includes user equipment 110 that communicate with at least one base station 112 in the RAN domain via a wireless interface. The RAN domain may also include a network controller (RNC) 118 (e.g., radio network controller), such as that used in UMTS systems. Alternatively, such functionality may be distributed between the Node Bs and an access gateway (AGW)(not shown) or other controller in the core network. Figure 1 also illustrates an optional radio resource manager (RRM) 114. The RRM may perform functions otherwise performed by the Node Bs or an AGW in some embodiments.

[0018] The core network (CN) 116 includes, in this example, a serving GPRS support node (SGSN) 120, and a gateway GPRS support node (GGSN) 122. The core network is coupled to an external network 124. The SGSN 120 is responsible for session control, including keeping track of

the location of the UEs. The GGSN 122 concentrates and tunnels user data within the core network 116 to the ultimate destination (e.g., an Internet service provider) in the external network 124. Further details may be found in the 3GPP UMTS technical specifications, such as TS23.246 v6.4.0 "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS); Architecture and Functional Description (Release 6)," published by the 3GPP Support Office, 650 Route des Lucioles - Sophia Antipolis, Valbonne - FRANCE, which are incorporated by reference herein.

[0019] Further details regarding exemplary communications systems that may implement embodiments of the invention may be found in 3GPP UMTS technical specifications, such as TR 23.882, "3GPP System Architecture Evolution: Report on Technical Options and Conclusions"; TR 25.912, "Feasibility Study for Evolved UTRA and UTRAN"; TS 23.101, "General Universal Mobile Telecommunications System (UMTS) Architecture," all of which are incorporated by reference herein.

TDD to FDD Evolution

[0020] A system designed for operation in Time Division Duplex (TDD) mode has base stations and terminals that transmit and receive at orthogonal points in time. In normal operation terminals are in receive mode when the base station is transmitting, and base stations are in receive mode when terminals are transmitting. In conventional TDD implementations, neither base stations nor the terminals are able to transmit and receive at the same points in time because the same frequency is used for uplink and downlink communication.

[0021] Such a system can be adjusted to operate in Frequency Division Duplex (FDD) mode, where the uplink and downlink communications occur on different frequencies. According to embodiments of the invention, to make full and efficient use of the frequency spectrum resources, the base stations are adapted to transmit and receive at the same time. This is possible since the uplink and downlink communications now occur on different frequencies. The terminals, however, retain the restriction of transmitting and receiving at orthogonal points in time to retain the simplicity of not having to transmit and receive at the same time (e.g., no duplexer required). The

full use of the frequency spectrum is then obtained by allocating the resource across a plurality of terminals.

[0022] Additional measures may be needed if there are aspects of the air interface that rely on the channel reciprocity that can be assumed for TDD systems. In the case of TD-CDMA, modifications may be made for the correct operation of uplink power control and rate adaptation. This can be achieved by defining an uplink physical control channel used for estimating the uplink channel conditions and a downlink channel used to feed back control information to the terminal. These channels may not need an associated data physical channel to be operational.

[0023] Modifications may be made to the random access channel. This may be achieved by introducing an additional indicator step at the start of any physical random access. A new uplink physical channel carries the random access indicators. A new downlink physical channel carries the response to received uplink indicators.

Uplink Physical Channel Control Signal

[0024] When pathloss reciprocity is not available, the combination of an uplink physical channel control signal with a downlink feedback channel may be used to keep the terminal informed of the condition of the uplink channel. The uplink physical control signal is referred to herein as an "Uplink Beacon" (UL_Beacon).

[0025] In general, a system that supports shared channels may also support shared access to a large number of terminals. To extract the maximum benefit from the resulting trunking gain, shared channels can be quickly and efficiently re-allocated between the population of UEs. To obtain rapid access to the uplink shared channels, terminals can transmit at the correct power with their first transmission so that latency can be kept to a minimum.

[0026] According to embodiments of the invention, the RNC or other controller (e.g., other controller having its functionality in the core network) allocates resources so that the physical channel control signal is separate from the uplink (shared) physical channel. Thus, terminals are able to transmit an UL_Beacon independently of their access to the uplink shared channel. The system may implement a closed loop control system, in which the base station detects the received

power and/or other channel information from the UL_Beacon, and sends controlling commands back to each terminal to keep the terminal informed of the channel conditions observed at the base station.

[0027] In certain embodiments, the closed loop control system is simply based on the UL_Beacon power received at the base station. The base station may send power control commands on a shared downlink channel to each terminal based on the power received from the UL_Beacon signal. Each power control command may, for example, indicate whether terminal power should be increased or decreased by a predetermined amount. This downlink channel is referred to as the "Physical Layer Control Channel" (PLCCH). The capacity of the PLCCH may be matched to the number of bits required in the feedback field and the number of UL_Beacon signals that can be simultaneously supported. That is, each UL_Beacon may correspond to one bit of the PLLCH. All terminals transmitting UL_Beacon signals may receive this channel and extract the relevant feedback field.

[0028] It is possible to extend the complexity of the control loop by sending control commands based on other aspects of the UL_Beacon signal as received by the base station, such as time-of-arrival, and channel impulse response. The amount of resource that is required for the feedback channel increases with the size (in bits) of the feedback information to each UE.

[0029] For example, for air interface technologies with a TDMA element, it is possible to adapt the TDMA frame structure to provide separation between the UL_Beacon and the normal physical channels by dedicating at least one uplink time slot per frame (or at least one time slot per multi-frame) to carrying UL_Beacon signals.

[0030] By placing UL_Beacon signals in a dedicated timeslot, a dedicated detection scheme can be applied which may include performance enhancing features such as intra-cell cancelling (for alleviating the effects of cross-correlation interference between UL_Beacon signals transmitted by multiple terminals in the same cell), or inter-cell cancelling (for reducing the interference from neighboring cells in the case where the UL_Beacon timeslots are time synchronized). Cross-interference between UL_Beacon and normal uplink bursts is avoided by the separation obtained from the use of separate time slots.

[0031] Those skilled in the art will recognize that there are a large number of possibilities for the arrangement of a UL_Beacon and its associated PLCCH within the frame structure according to embodiments of the invention. More than one UL_Beacon and PLCCH per frame could be supported if the feedback update rate is required to be faster than the frame rate (at the expense of system capacity). For system applications that can tolerate a slower feedback rate, embodiments may fractionate the use of the UL_Beacon timeslot (and the associated PLCCH).

[0032] When fractionation is employed, the RNC or other controller may allocate the UL_Beacon timeslot in a given frame to a group of terminals depending on the current fractionation phase, thus increasing the number of terminals that can be supported with active physical channel feedback control. The maximum fractionation cycle length may be determined by the feedback update rate that the system requires in order to meet its performance targets.

[0033] Figure 2 illustrates an example of a timeslot arrangement supporting the UL_Beacon and its corresponding PLCCH within a TD-CDMA frame structure modified to support FDD. In this example, the PLCCH 212 shares a timeslot with another downlink shared channel. This is possible since normal downlink physical channels are used to transmit the PLCCH. The downlink frame also comprises a downlink beacon timeslot 206, an access control timeslot 208, and normal traffic carrying timeslots 210. The uplink frame comprises a UL_Beacon control timeslot 216, an access control timeslot 218, and normal traffic carrying timeslots 214.

[0034] Figure 3 illustrates an example where fractionation is employed. The UL_Beacon and PLCCH timeslots are active in every frame at the base station 302. However, terminal 304, terminal 306, and terminal 308 have been assigned a different fractionation phase. Figure 3 illustrates the case where the fractionation phase is 3. For example, the fractionation phase of terminal 304 occurs in frame #0 310, the fractionation phase of terminal 306 occurs in frame #1 312, and the fractionation phase of terminal 308 occurs in frame #2. Since the fractionation phase is 3, the phase for terminal 304 occurs again in frame #3 316.

Half Duplex Terminals

[0035] Embodiments of the invention enable terminals to operate in half duplex or full duplex mode. In a half duplex system, base stations and terminals do not transmit and receive simultaneously. When such a system is evolved to operate in paired spectrum, it becomes inefficient if base stations retain their half duplex operation. It is not necessarily inefficient for the terminals to do so, however, since half duplex operation may have some advantages in the design and implementation of the terminal.

[0036] Nonetheless, there are some points that should be considered. For example, a single terminal may not be able to access all transmit and all receive slots. Therefore, the system may have to manage resources across the population of terminals to ensure all the available resources at the base station are efficiently utilized. To prevent blocking of timeslots, half duplex terminals may be operated with a fractionation cycle of greater than one. In particular, this may also apply for the case where there are more than one UL_Beacon timeslot per frame. There is a time delay for half duplex terminals to switch between transmit and receive functions. In some cases this delay exceeds the guard period inserted between consecutive timeslots. In the half duplex terminal case, the terminal is unable to transmit and receive on adjacent timeslots. This will affect the locations of the UL_Beacon, PLCCH, and other common channels. Accordingly, the timeslot arrangement may be adjusted when the system is configured.

Terminal Management

[0037] Embodiments of this invention separate uplink control from the uplink physical traffic. This allows the control feedback to operate even when the terminal does not have data to send, with the consequence that uplink shared channels can be used with maximum efficiency.

[0038] To use shared channels efficiently, a relatively large user base may be needed. At the same time, the network resources required to support the control feedback channels for these terminals need to be minimized. In general, the number of users that can be supported with active control feedback channels is smaller than the typical number of users per cell. Therefore, the terminals in this active state may be managed.

[0039] In UMTS terminology, embodiments of the invention provide a new Universal Terrestrial Radio Access- Radio Resource Control-Connected (UTRA RRC-Control) sub-state into the system. UTRA systems already support the idea of different RRC-Connected states (see, TS25.331 Radio Resource Control (RRC) Protocol Specification, which is incorporated herein by reference), e.g., CELL_DCH, CELL_FACH etc. This sub-state is referred to as the CELL_ACTIVE state. Figure 4 illustrates this sub-state in context with other UTRA RRC-connected states. A UE in a Cell_Active sub-state transmits the physical channel control part of the uplink physical channel only, and nothing else (i.e., no data).

[0040] As shown in Figure 4, CELL_ACTIVE sub-state is a sub-state of CELL_FACH state 404. In general, UEs in CELL_FACH state have an RRC connection, but they may not be actively transferring data. Out of the population of UEs in CELL_FACH state 404, a smaller number of UEs, determined by the network to be the most-active UEs, are supported in a CELL_ACTIVE state 406. In this state, the UEs transmit the physical channel control signal and listen to the associated feedback channel from the network. Because the UE is aware of the uplink pathloss conditions from the feedback channel, it can have instant access to the uplink shared channels, and the resource allocator (controller) in the network can treat the UE accordingly.

[0041] The rules governing which UEs are maintained in CELL_ACTIVE state are decided by the network (e.g., through the RNC) and may be based on factors such as the volume of data transfer required by the UE, the data transfer rate required by a UE, the frequency of short bursts of data transfer, the total number of UEs in CELL_FACH state, the time since the last data transfer, the UE power saving requirements, etc.

[0042] Note that UEs in CELL_ACTIVE state have their transmitters active, therefore it is necessary for these UEs to monitor the status of the downlink and automatically come out of CELL_ACTIVE state if the downlink is deemed to be out-of-synchronization (for example, very high downlink errors or low received signal strength). This feature prevents UEs continuing to transmit in a state where the feedback channel may be unreliable and thus causing interference.

[0043] While the invention has been described in terms of particular embodiments and illustrative figures, those of ordinary skill in the art will recognize that the invention is not limited to

the embodiments or figures described. Although embodiments of the present invention are described, in some instances, using UMTS terminology, those skilled in the art will recognize that such terms are also used in a generic sense herein, and that the present invention is not limited to such systems.

[0044] Those skilled in the art will recognize that the operations of the various embodiments may be implemented using hardware, software, firmware, or combinations thereof, as appropriate. For example, some processes can be carried out using processors or other digital circuitry under the control of software, firmware, or hard-wired logic. (The term "logic" herein refers to fixed hardware, programmable logic and/or an appropriate combination thereof, as would be recognized by one skilled in the art to carry out the recited functions.) Software and firmware can be stored on computer-readable media. Some other processes can be implemented using analog circuitry, as is well known to one of ordinary skill in the art. Additionally, memory or other storage, as well as communication components, may be employed in embodiments of the invention.

[0045] Figure 5 illustrates a typical computing system 500 that may be employed to implement processing functionality in embodiments of the invention. Computing systems of this type may be used in the the radio controllers, the base stations, and the UEs, for example. Those skilled in the relevant art will also recognize how to implement the invention using other computer systems or architectures. Computing system 500 may represent, for example, a desktop, laptop or notebook computer, hand-held computing device (PDA, cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment. Computing system 500 can include one or more processors, such as a processor 504. Processor 504 can be implemented using a general or special purpose processing engine such as, for example, a microprocessor, microcontroller or other control logic. In this example, processor 504 is connected to a bus 502 or other communications medium.

[0046] Computing system 500 can also include a main memory 508, such as random access memory (RAM) or other dynamic memory, for storing information and instructions to be executed by processor 504. Main memory 508 also may be used for storing temporary variables or other

intermediate information during execution of instructions to be executed by processor 504. Computing system 500 may likewise include a read only memory ("ROM") or other static storage device coupled to bus 502 for storing static information and instructions for processor 504.

[0047] The computing system 500 may also include information storage system 510, which may include, for example, a media drive 512 and a removable storage interface 520. The media drive 512 may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a CD or DVD drive (R or RW), or other removable or fixed media drive. Storage media 518, may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive 514. As these examples illustrate, the storage media 518 may include a computer-readable storage medium having stored therein particular computer software or data.

[0048] In alternative embodiments, information storage system 510 may include other similar components for allowing computer programs or other instructions or data to be loaded into computing system 500. Such components may include, for example, a removable storage unit 522 and an interface 520, such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units 522 and interfaces 520 that allow software and data to be transferred from the removable storage unit 518 to computing system 500.

[0049] Computing system 500 can also include a communications interface 524. Communications interface 524 can be used to allow software and data to be transferred between computing system 500 and external devices. Examples of communications interface 524 can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a USB port), a PCMCIA slot and card, etc. Software and data transferred via communications interface 524 are in the form of signals which can be electronic, electromagnetic, optical or other signals capable of being received by communications interface 524. These signals are provided to communications interface 524 via a channel 528. This channel 528 may carry signals and may be implemented using a wireless medium, wire or cable, fiber

optics, or other communications medium. Some examples of a channel include a phone line, a cellular phone link, an RF link, a network interface, a local or wide area network, and other communications channels.

[0050] In this document, the terms "computer program product," "computer-readable medium" and the like may be used generally to refer to media such as, for example, memory 508, storage device 518, or storage unit 522. These and other forms of computer-readable media may store one or more instructions for use by processor 504, to cause the processor to perform specified operations. Such instructions, generally referred to as "computer program code" (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system 500 to perform functions of embodiments of the present invention. Note that the code may directly cause the processor to perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

[0051] In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system 500 using, for example, removable storage drive 514, drive 512 or communications interface 524. The control logic (in this example, software instructions or computer program code), when executed by the processor 504, causes the processor 504 to perform the functions of the invention as described herein.

[0052] It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processors or domains may be used without detracting from the invention. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same processor or controller. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[0053] Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention.

[0054] Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather the feature may be equally applicable to other claim categories, as appropriate.

CLAIMS

What is claimed is:

1. A method for enabling active control feedback between a base station and user equipment (UE) in a wireless communications network, the method comprising:

allocating a first time slot within a frame for a UE to transmit a beacon signal to the base station, wherein the beacon signal is separate from data signals in the frame;

allocating a second time slot within the frame for the base station to transmit a control signal in response to the beacon signal, the control signal for providing a basis upon which the UE adjusts a transmission parameter; and

allocating other timeslots for the base station to operate in full duplex FDD mode.

2. The method of claim 1, wherein data signals are not allocated to the first time slot.

3. The method of claim 1, wherein the first and second time slots operate in full duplex FDD mode.

4. The method of claim 1, wherein the transmission parameter comprises power.

5. The method of claim 1, wherein the control signal is based upon at least one factor from the group consisting of: path loss computed based upon the received power of the beacon signal; time of arrival of the beacon signal; and channel impulse response in response to the beacon signal.

6. The method of claim 1, wherein allocating a second time slot to the control signal comprises allowing another downlink signal, separated in the code domain from the control signal, to share the second time slot with the control signal.

7. The method of claim 1, wherein

allocating a first time slot within a frame for the UE comprises allocating the first time slot within at least some successive frames to different UEs for transmission of respective different beacon signals, and

allocating a second time slot within a frame for the base station comprises allocating the second time slot to the base station for transmission of different control signals within the at least some successive frames to the different UEs .

8. The method of claim 1, further comprising determining to which UE the first time slot should be allocated based upon at least one factor from the group consisting of: expected volume of data transfer expected; required data transfer rate; frequency of short bursts of data transfer; total number of UEs connected to the network; time since last data transfer; and UE power saving requirements.

9. A controller for enabling active control feedback between a base station and UE in a wireless communications network, the controller comprising logic for:

allocating a first time slot within a frame for a UE to transmit a beacon signal to the base station, wherein the beacon signal is separate from data signals in the frame;

allocating a second time slot within the frame for the base station to transmit a control signal in response to the beacon signal, the control signal for providing a basis upon which the UE adjusts a transmission parameter; and

allocating other timeslots for the base station to operate in full duplex FDD mode.

10. The controller of claim 9, wherein data signals are not allocated to the first time slot.

11. The controller of claim 9, wherein the first and second time slots operate in full duplex FDD mode.

12. The controller of claim 9, wherein the transmission parameter comprises power.

13. The controller of claim 9, wherein the control signal is based upon at least one factor from the group consisting of: path loss computed based upon the received power of the beacon signal; time of arrival of the beacon signal; and channel impulse response in response to the beacon signal.

14. The controller of claim 9, wherein the logic for allocating a second time slot to the control signal comprises logic for allowing another downlink signal, separated in the code domain from the control signal, to share the second time slot with the control signal.

15. The controller of claim 9, wherein

the logic for allocating a first time slot within a frame for the UE comprises logic for allocating the first time slot within at least some successive frames to different UEs for transmission of respective different beacon signals, and

the logic for allocating a second time slot within a frame for the base station comprises logic for allocating the second time slot to the base station for transmission of different control signals within the at least some successive frames to the different UEs .

16. The controller of claim 9, further comprising logic for determining to which UE the first time slot should be allocated based upon at least one factor from the group consisting of: expected volume of data transfer expected; required data transfer rate; frequency of short bursts of data transfer; total number of UEs connected to the network; time since last data transfer; and UE power saving requirements.

17. A computer-readable medium comprising program code for enabling active control feedback between a base station and UE in a wireless communications network, the program code for:

allocating a first time slot within a frame for a UE to transmit a beacon signal to the base station, wherein the beacon signal is separate from data signals in the frame;

allocating a second time slot within the frame for the base station to transmit a control signal in response to the beacon signal, the control signal for providing a basis upon which the UE adjusts a transmission parameter; and

allocating other timeslots for the base station to operate in full duplex FDD mode.

18. The computer-readable medium of claim 17, wherein data signals are not allocated to the first time slot.

19. The computer-readable medium of claim 17, wherein the first and second time slots operate in full duplex FDD mode.

20. The computer-readable medium of claim 17, wherein the transmission parameter comprises power.

21. The computer-readable medium of claim 17, wherein the control signal is based upon at least one factor from the group consisting of: path loss computed based upon the received power of the beacon signal; time of arrival of the beacon signal; and channel impulse response in response to the beacon signal.

22. The computer-readable medium of claim 17, wherein the program code for allocating a second time slot to the control signal comprises program code for allowing another downlink signal, separated in the code domain from the control signal, to share the second time slot with the control signal.

23. The computer-readable medium of claim 17, wherein

the program code for allocating a first time slot within a frame for the UE comprises program code for allocating the first time slot within at least some successive frames to different UEs for transmission of respective different beacon signals, and

the program code for allocating a second time slot within a frame for the base station comprises program code for allocating the second time slot to the base station for transmission of different control signals within the at least some successive frames to the different UEs .

24. The computer-readable medium of claim 17, further comprising program code for determining to which UE the first time slot should be allocated based upon at least one factor from the group consisting of: expected volume of data transfer expected; required data transfer rate; frequency of short bursts of data transfer; total number of UEs connected to the network; time since last data transfer; and UE power saving requirements.

ABSTRACT

Active control feedback between a base station and user equipment in a wireless communications network is achieved by allocating a first time slot within a frame for a UE to transmit a beacon signal to the base station, where the beacon signal is separate from data signals in the frame, allocating a second time slot within the frame for the base station to transmit a control signal in response to the beacon signal, and allocating other timeslots for the base station to operate in full duplex FDD mode. The control signal provides a basis upon which the UE adjusts a transmission parameter, such as power.

Ex.1006 / Page 26 of 823
TESLA, INC.

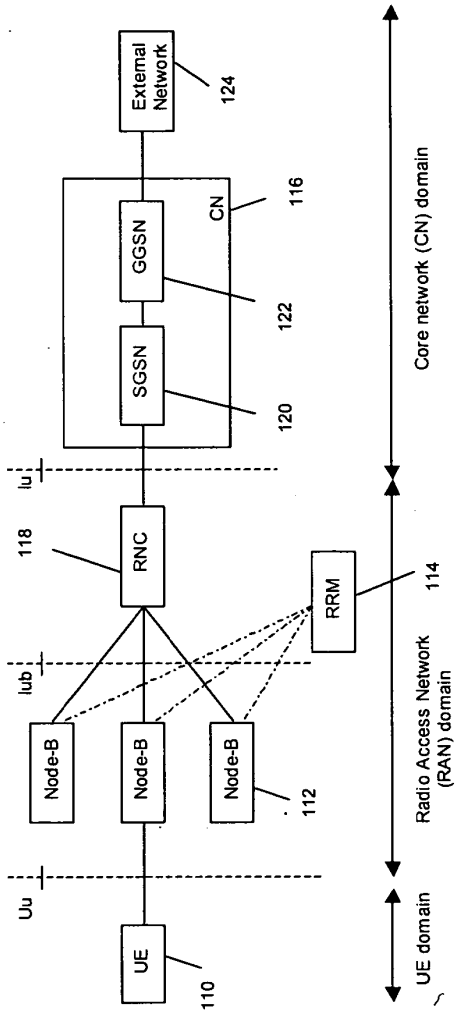

External Network
124
CN
116
GGSN
122
SGSN
120
Iu
118
RNC
RRM
114
Iub
Node-B
Node-B
Node-B
112
Uu
UE
110
Core network (CN) domain
Radio Access Network (RAN) domain
UE domain

Figure 1

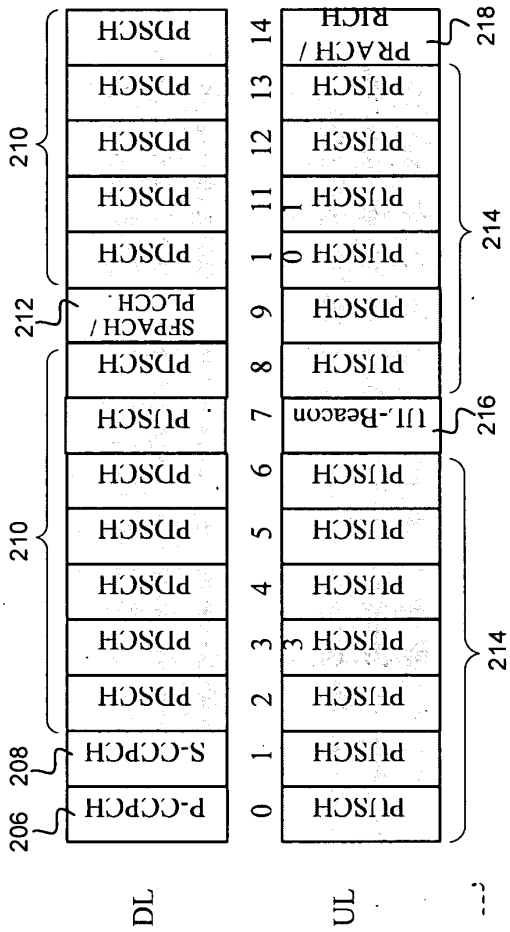


Figure 2

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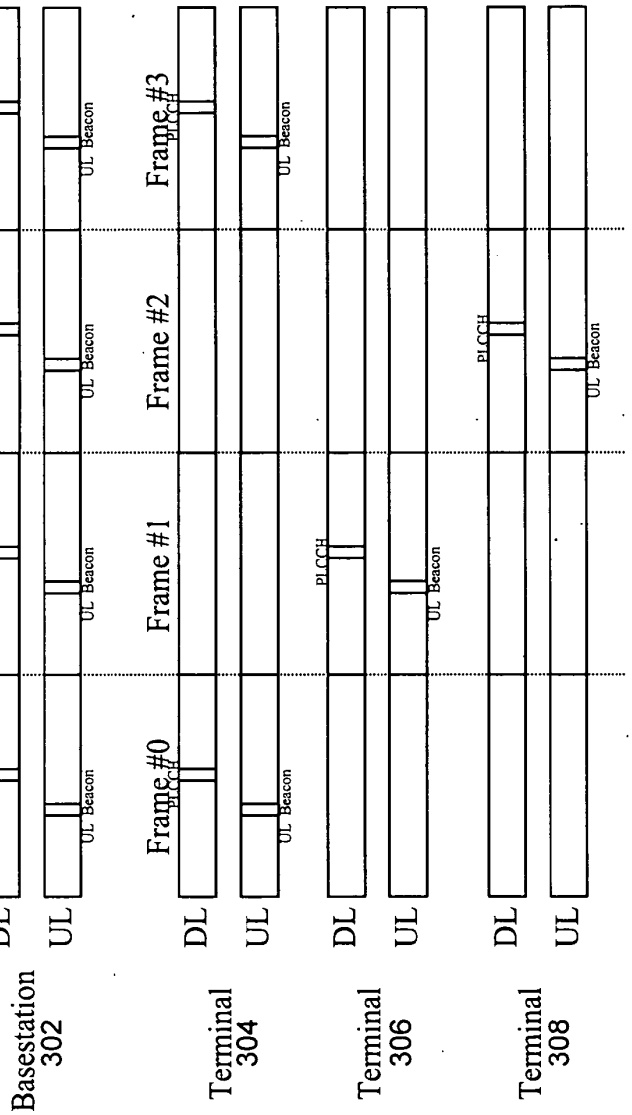

310
312
314
316
Frame #0
Frame #1
Frame #2
Frame #3
PLCCH
UL Beacon
DL
UL
Basestation 302
Terminal 304
Terminal 306
Terminal 308

Figure 3

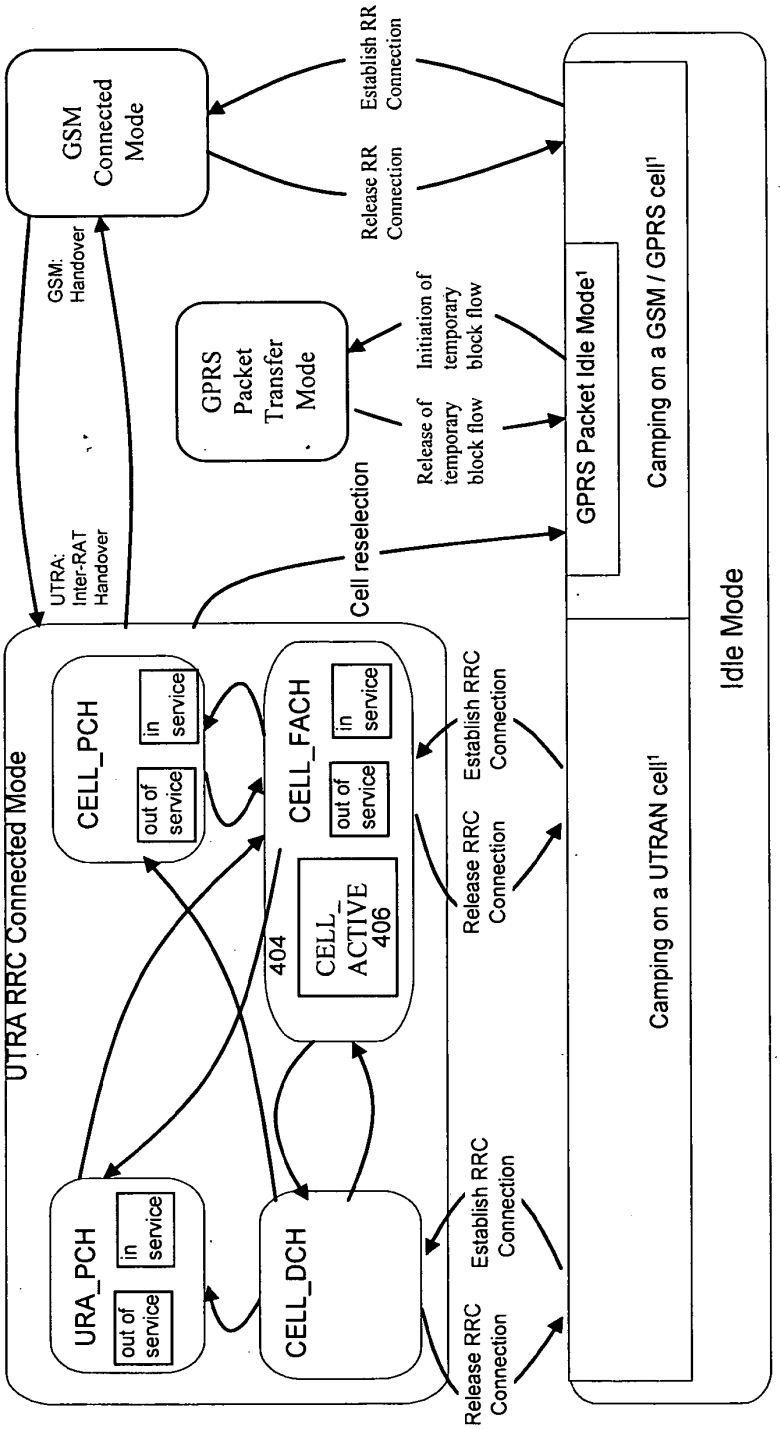

GSM Connected Mode
Establish RR Connection
Release RR Connection
GSM: Handover
UTRA: Inter-RAT Handover
GPRS Packet Transfer Mode
Initiation of temporary block flow
Release of temporary block flow
Cell reselection
GPRS Packet Idle Mode[1]
Camping on a GSM / GPRS cell[1]
UTRA RRC Connected Mode
CELL_PCH
in service
out of service
CELL_FACH
in service
out of service
404
CELL_ ACTIVE 406
Release RRC Connection
Establish RRC Connection
URA_PCH
in service
out of service
CELL_DCH
Release RRC Connection
Establish RRC Connection
Camping on a UTRAN cell[1]
Idle Mode

Figure 4

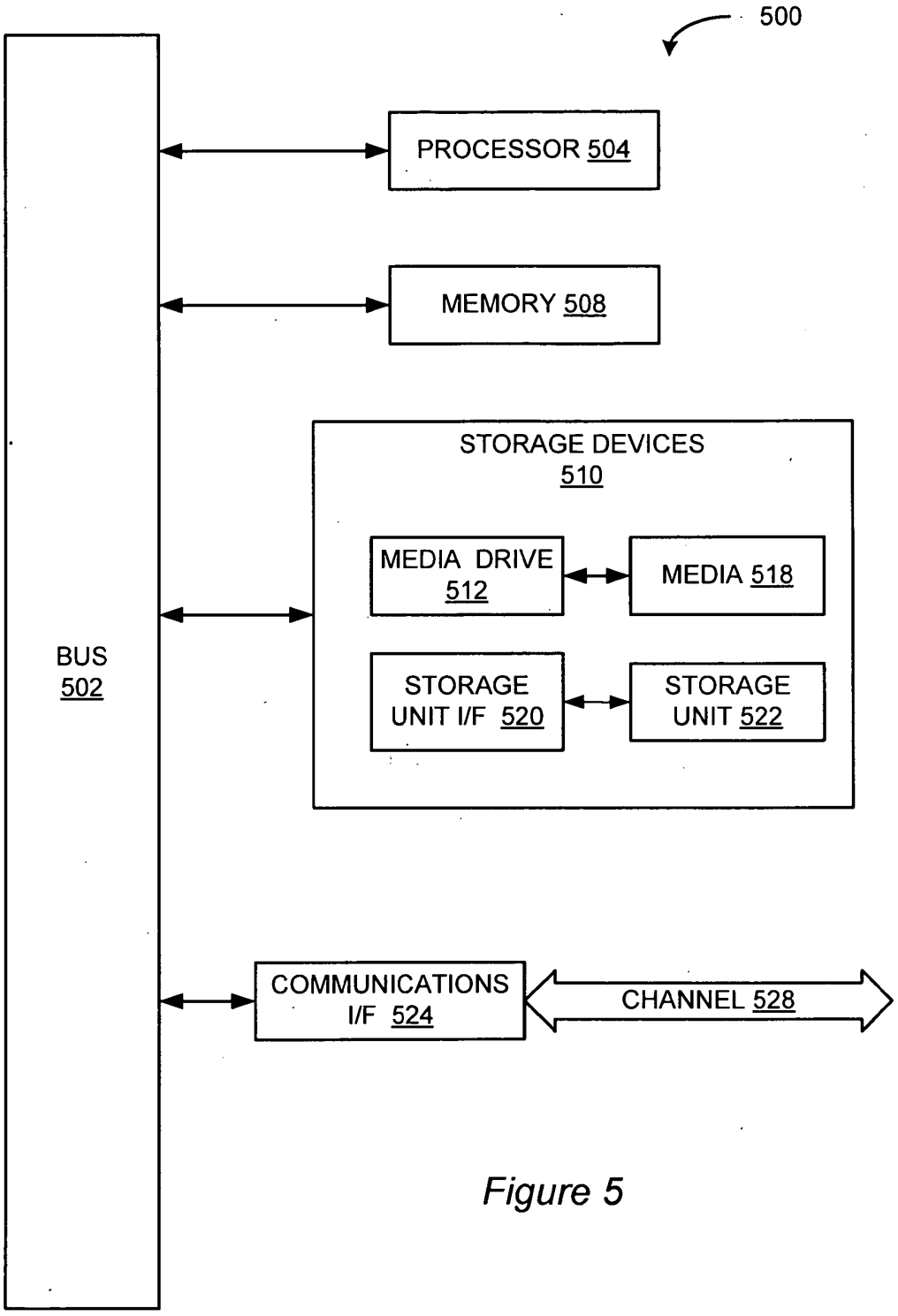

500
PROCESSOR 504
MEMORY 508
STORAGE DEVICES 510
MEDIA DRIVE 512
MEDIA 518
STORAGE UNIT I/F 520
STORAGE UNIT 522
BUS 502
COMMUNICATIONS I/F 524
CHANNEL 528

Figure 5

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM

As the below named inventor(s), I/we declare that:

This declaration is directed to:

☐ The attached application, or

☒ Application No. 11/648,692 , filed on 12/27/2006

☐ as amended on _____ (if applicable);

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought.

I/we have reviewed and understand the contents of the above-identified application, including the claims, as amended by any amendment specifically referred to above.

I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

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All statements made herein of my/our own knowledge are true, all statements made herein on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and may jeopardize the validity of the application or any patent issuing thereon.

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Inventor two: _____

Signature: _____ Citizen of: _____

Inventor three: _____

Signature: _____ Citizen of: _____

Inventor four: _____

Signature: _____ Citizen of: _____

☐ Additional inventors or a legal representative are being named on _____ additional form(s) attached hereto.

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Electronic Patent Application Fee Transmittal	
Application Number:	
Filing Date:	
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Filer:	Steven Glen Parmelee/Helen Donegan
Attorney Docket Number:	9147-99460-US
Filed as Large Entity	

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	330	330
Utility Search Fee	1111	1	540	540
Utility Examination Fee	1311	1	220	220
Pages:				
Claims:				
Claims in excess of 20	1202	4	52	208
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		1298

Electronic Acknowledgement Receipt	
EFS ID:	10451996
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9147-99460-US
Receipt Date:	05-JUL-2011
Filing Date:	
Time Stamp:	16:05:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1298
RAM confirmation Number	2704
Deposit Account	061135
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	99460_Utility_Patent_Application_Transmittal.pdf	244156 c9db05fa372da722179d75da9a6360d66d0a0bdf	no	2
Warnings:					
Information:					
2	Authorization for Extension of Time all replies	99460_GeneralAuthorizationForPetitionForExtensionOfTime_1.PDF	43016 d7bf45f7f54abeb4375492bfbd2435d853eb8d7d	no	1
Warnings:					
Information:					
3	Application Data Sheet	99460_Application_Data_Sheet.pdf	964780 3b2081062fe1e0c7e615527ae975b8d83a308f4b	no	4
Warnings:					
Information:					
4		99460_Specification_Claims_Abstract.pdf	877010 a28e9f6b3cea882f7ad45743b1341872afdab3ac	yes	19

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	14
Claims	15	18
Abstract	19	19

Warnings:					
Information:					
5	Drawings-only black and white line drawings	99460_Drawings.pdf	84345 306ef1d7de2ba3db404036abbe5b27f7e3cb4e60	no	5
Warnings:					
Information:					
6	Oath or Declaration filed	99460_Declaration.pdf	69869 cc4aafcd67e8fabcddae3c5d4bf73f081b10cecc	no	1
Warnings:					
Information:					

7	Fee Worksheet (SB06)	fee-info.pdf	36652 34b4e96cfc80903cdf89d418155b21e4e364f318	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	2319828	

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

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

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

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

PTO/SB/96 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Paul Howard

Application No./Patent No.: 13/176,298 Filed/Issue Date: July 5, 2011

Titled: Feedback Control in an FDD TDD-CDMA System

Wireless Technology Solutions LLC , a corporation

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

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;

2. ☐ an assignee of less than the entire right, title, and interest in (The extent (by percentage) of its ownership interest is _____ %); or

3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

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

OR

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

1. From: See Attached Patent Abstract of Title To: _____

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

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

2. From: _____ To: _____

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

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

3. From: _____ To: _____

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

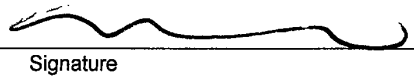
Reel _____, Frame _____, or for which a copy thereof is attached.

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

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

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

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



Signature July 5, 2011 Date

Steven G. Parmelee Printed or Typed Name

Attorney for Applicant Title

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

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PTO/SB/80 (11-08)
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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☑ Practitioners associated with the Customer Number: 22242

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3 73(b) to:

☑ The address associated with Customer Number: 22242

OR

☐ Firm or individual Name			
Address			
City		State	Zip
Country			
Telephone		Email	

Assignee Name and Address:

Wireless Technology Solutions LLC
550 Madison Avenue
New York, New York 10022

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	4/11/2011
Name	ED SCHUMMER	Telephone	+1-415-874-9541
Title	CEO		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

11/646,692 FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM 9147-96652-US 07-05-2011::16:02:57

Patent Assignment Abstract of Title

Total Assignments: 6

Application #: 11646692 **Filing Dt:** 12/27/2006 **Patent #:** NONE **Issue Dt:**
PCT #: NONE **Publication #:** US20080159185 **Pub Dt:** 07/03/2008
Inventor: Paul Howard
Title: FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM

Assignment: 1

Reel/Frame: 019106 / 0467 **Received:** 04/03/2007 **Recorded:** 04/03/2007 **Mailed:** 04/04/2007 **Pages:** 2
Conveyance: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).
Assignor: HOWARD, PAUL **Exec Dt:** 04/03/2007
Assignee: IPWIRELESS, INC.
1001 BAYHILL DRIVE, SECOND FLOOR
SAN BRUNO, CALIFORNIA 94066
Correspondent: ROBERT A. SALTZBERG
MORRISON & FOERSTER LLP
425 MARKET STREET
SAN FRANCISCO, CA 94105

Assignment: 2

Reel/Frame: 022102 / 0891 **Received:** 01/14/2009 **Recorded:** 01/14/2009 **Mailed:** 01/15/2009 **Pages:** 25
Conveyance: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).
Assignor: IPWIRELESS, INC. **Exec Dt:** 12/24/2008
Assignee: NORTHROP GRUMMAN INFORMATION TECHNOLOGY, INC.
1840 CENTURY PARK EAST
LOS ANGELES, CALIFORNIA 90067-2199
Correspondent: COLMAN B. RAGAN
787 SEVENTH AVENUE
WILLKIE FARR & GALLAGHER LLP
NEW YORK, NY 10019

Assignment: 3

Reel/Frame: 024006 / 0144 **Received:** 03/01/2010 **Recorded:** 03/01/2010 **Mailed:** 03/01/2010 **Pages:** 38
Conveyance: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).
Assignor: NORTHROP GRUMMAN INFORMATION TECHNOLOGY, INC. **Exec Dt:** 11/03/2009
Assignee: IPWIRELESS, INC.
90 NEW MONTGOMERY STREET
SUITE 315
SAN FRANCISCO, CALIFORNIA 94105
Correspondent: FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

Assignment: 4

Reel/Frame: 024233 / 0065 **Received:** 04/14/2010 **Recorded:** 04/14/2010 **Mailed:** 04/15/2010 **Pages:** 19
Conveyance: AMENDED AND RESTATED PATENT SECURITY AGREEEMENT
Assignors: IPWIRELESS, INC. **Exec Dt:** 11/03/2009
IPWIRELESS U.K. LIMITED **Exec Dt:** 11/03/2009
IPW HOLDINGS, INC. **Exec Dt:** 11/03/2009
IPWIRELESS PTE LIMITED **Exec Dt:** 11/03/2009
Assignee: NORTHROP GRUMMAN INFORMATION TECHNOLOGY, INC. NOW KNOWN AS NORTHROP GRUMMAN SYSTEMS CORPORATION BY REASON OF MERGER
1840 CENTURY PARK EAST
LOS ANGELES, CALIFORNIA 90067
Correspondent: WILLKIE FARR & GALLAGHER
787 SEVENTH AVENUE
CARE OF COLMAN B. RAGAN
NEW YORK, NY 10019

Assignment: 5

Reel/Frame: 024305 / 0231 **Received:** 04/29/2010 **Recorded:** 04/29/2010 **Mailed:** 04/29/2010 **Pages:** 13
Conveyance: RELEASE BY SECURED PARTY (SEE DOCUMENT FOR DETAILS).
Assignor: NORTHROP GRUMMAN SYSTEMS CORPORATION (SUCCESSOR BY MERGER TO NORTHROP GRUMMAN INFORMATION TECHNOLOGY, INC.) **Exec Dt:** 04/23/2010
Assignee: IPWIRELESS, INC.
90 NEW MONTGOMERY STREET

SUITE 315
SAN FRANCISCO, CALIFORNIA 94105

Correspondent: TIMOTHY FRANKLIN
599 LEXINGTON AVENUE
SHEARMAN & STERLING LLP - IP DOCKETING
NEW YORK, NY 10022

Assignment: 6

Reel/Frame: 024305 / 0492 **Received:** 04/29/2010 **Recorded:** 04/29/2010 **Mailed:** 04/29/2010 **Pages:** 8

Conveyance: ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).

Assignor: IP WIRELESS, INC. **Exec Dt:** 04/23/2010

Assignee: WIRELESS TECHNOLOGY SOLUTIONS LLC
550 MADISON AVENUE
NEW YORK, NEW YORK 10022

Correspondent: OBLON, SPIVAK, ET AL.
1940 DUKE STREET
ALEXANDRIA, VA 22314

Search Results as of: 07/05/2011 16:02:54 PM

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

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt

EFS ID:	10453670
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9147-99460-US
Receipt Date:	05-JUL-2011
Filing Date:	
Time Stamp:	17:14:45
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	99460_Power_of_Attorney_1.PDF	292855 6887e6b6e6872cbfe51f4ab25fea64e053e2b0a0	no	5

Warnings:	
Information:	

Total Files Size (in bytes):	292855

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New International Application Filed with the USPTO as a Receiving Office
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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/176,298	07/05/2011	Paul Howard	9147-99460-US

CONFIRMATION NO. 4342

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

FORMALITIES LETTER

OC000000048800841

Date Mailed: 07/19/2011

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
  - Numbers, letters, and reference characters on the drawings must measure at least 0.32 cm (1/8 inch) in height. See Figure(s) 3.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

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Commissioner for Patents
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/hnguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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UNITED STATES DEPARTMENT OF COMMERCE
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www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/176,298	07/05/2011	2473	1298	9147-99460-US	24	3

CONFIRMATION NO. 4342

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

FILING RECEIPT

OC000000048800840

Date Mailed: 07/19/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Paul Howard, Briston, UNITED KINGDOM;

Assignment For Published Patent Application

WIRELESS TECHNOLOGY SOLUTIONS LLC, New York, NY

Power of Attorney: The patent practitioners associated with Customer Number 22242

Domestic Priority data as claimed by applicant

This application is a CON of 11/646,692 12/27/2006

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 07/14/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/176,298**

Projected Publication Date: To Be Determined - pending completion of Corrected Papers

Non-Publication Request: No

Early Publication Request: No

Title

Feedback Control in an FDD TDD-CDMA System

Preliminary Class

370

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/176,298	07/05/2011	Paul Howard	9147-99460-US

CONFIRMATION NO. 4342

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

POA ACCEPTANCE LETTER

OC000000048776474

Date Mailed: 07/19/2011

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 07/05/2011.

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

/llvuong/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/176,298

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	330
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	540
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	220
TOTAL CLAIMS (37 CFR 1.16(i))	24 minus 20 =	* 4			OR	x 52 =	208
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 220 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $270 ($135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1298

APPLICATION AS AMENDED - PART II

AMENDMENT A

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

AMENDMENT B

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.: 13/176,298	Confirmation No. 4342
Filed: July 5, 2011	This Response to Notice to File Corrected Application Papers was electronically filed on August 2, 2011 using the U.S. Patent and Trademark Office's EFS Web
Applicant: Paul Howard	
Title: FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM	
Art Unit: 2473	
Examiner: Not Yet Assigned	
Attorney Docket No.: 9147-99460-US	
Customer No.: 22242	

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

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

Sir:

In response to the Notice to File Corrected Application Papers dated March 28, 2011

☐ A copy of the Notice to File Missing Parts is enclosed.

☐ A Preliminary Amendment is enclosed.

☐ An Application Data Sheet 37 CFR 1.76, is enclosed.

☒ 1 sheet of drawings are enclosed. ☒ Formal ☐ Informal

☐ An Assignment of the invention to _____, and Recordation Form Cover Sheet - Patents Only - Form PTO-1595, are enclosed.

☐ A check in the amount of $_____ to cover the fee for recording the assignment is enclosed.

☐ The Recordation Form Cover Sheet includes authorization to charge our Deposit Account for recording the assignment.

☒ The fees are calculated below:

☐	Provisional Application Filing Fee				$ 200.00		
	Application size fee for each additional 50 sheets that exceeds 100 sheets				x $ 250.00	=	$
	Surcharge Fee				$ 50.00		
	Search Fee				$ 100.00		
	Examination Fee				$ 130.00		
	Total Fees					$	0.00
	☐ Applicant(s) assert entitlement to Small Entity Status (37 C.F.R. § 1.27), reducing the Total Fees by half to:					$	0.00
☒	Basic Filing Fee - Utility				$ 300.00		
	Independent Claims	- 3	= 0	x	$ 200.00	= $	0.00
	Total Claims	- 20	= 0	x	$ 50.00	= $	0.00
	Fee for Multiple Dependent Claims				$ 360.00		
	Surcharge Fee				$ 130.00	$	
	Application Size Fee for each additional 50 sheets that exceeds 100 sheets				x $ 250.00	=	
	Search Fee				$ 500.00		
	Examination Fee				$ 200.00		
	Total Fees					$	
	☐ Applicant(s) assert entitlement to Small Entity Status (37 C.F.R. § 1.27), reducing the Total Fees by half to:						
☐	Basic Filing Fee - Design				$ 200.00		
	Surcharge Fee				$ 130.00		
	Search Fee				$ 100.00		
	Examination Fee				$ 130.00		
	Total Fees					$	0.00

Missing Parts 2-1204

☐ Applicant(s) assert entitlement to Small Entity Status (37 C.F.R. § 1.27), reducing the Total Fees by half to: $ 0.00

☐ A check in the amount of $_____ to cover the above fees is enclosed.

☒ Charge $_____to Deposit Account No. 06-1135.

☒ The Commissioner is hereby authorized to charge any additional fees which may be required in this application under 37 C.F.R. §§1.16-1.17 during its entire pendency, or credit any overpayment, to Deposit Account No. 06-1135. Should no proper payment be enclosed herewith, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 06-1135. This sheet is filed in duplicate.

August 2, 2011
Date

Steven G. Parmelee
Registration No. 28,790

FITCH, EVEN, TABIN & FLANNERY
120 South LaSalle Street, Suite 1600
Chicago, Illinois 60603-3406
Telephone: (312) 577-7000
Facsimile: (312) 577-7007

Missing Parts 3-1204

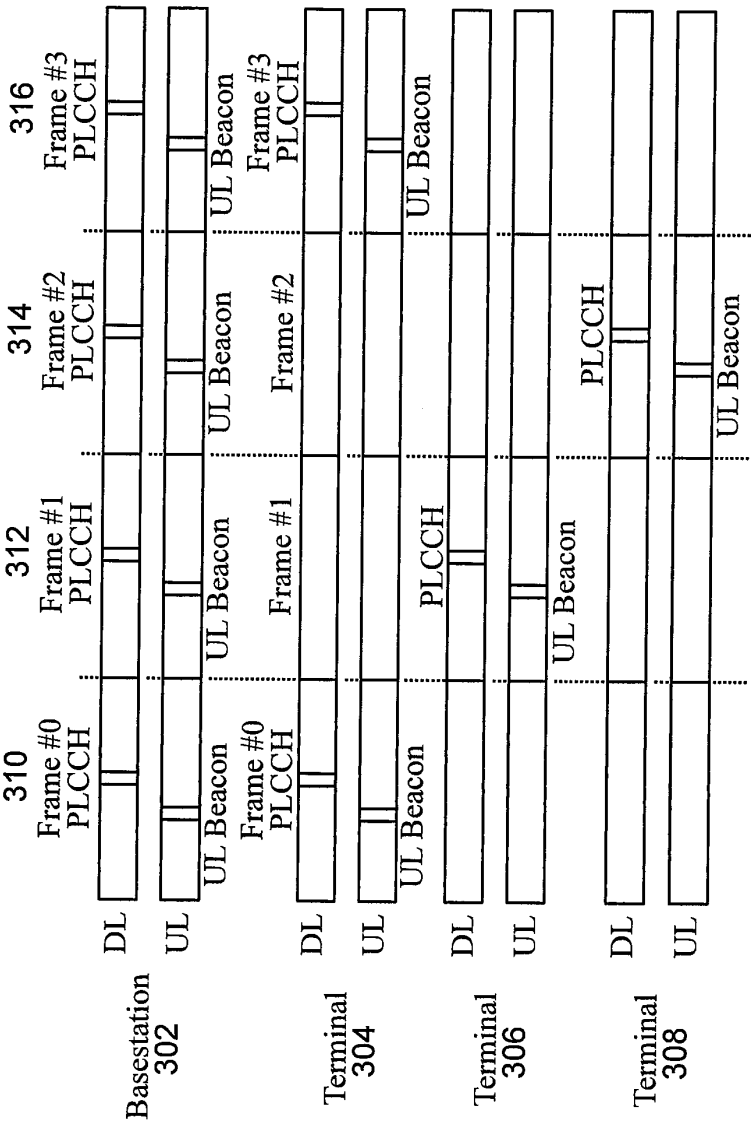

Basestation 302
Terminal 304
Terminal 306
Terminal 308
DL
UL
310
Frame #0 PLCCH
UL Beacon
312
Frame #1 PLCCH
UL Beacon
314
Frame #2 PLCCH
UL Beacon
316
Frame #3 PLCCH
UL Beacon
Frame #0 PLCCH
Frame #1
Frame #2
Frame #3 PLCCH
UL Beacon
PLCCH
UL Beacon
PLCCH
UL Beacon

Figure 3

Electronic Acknowledgement Receipt

EFS ID:	10649594
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9147-99460-US
Receipt Date:	02-AUG-2011
Filing Date:	05-JUL-2011
Time Stamp:	15:47:23
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Response to Pre-Exam Formalities Notice	99460_ResponseToNoticeToFileCorrectedApplicationPapers_1.PDF	90273 b60bcc84830ef7052047f44c7f811b5d15f5ccba	no	3

Warnings:	
Information:	

2	Drawings-only black and white line drawings	99460_Drawing_Sheet_3_1.PDF	22318 a3298abc0d7a1823a8e1734ebc1cc99b55436107	no	1
Warnings:					
Information:					
			Total Files Size (in bytes):	112591	

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

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

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

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

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/176,298

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
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SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	540
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	220
TOTAL CLAIMS (37 CFR 1.16(i))	24 minus 20 =	* 4			OR	x 52 =	208
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 220 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $270 ($135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1298

APPLICATION AS AMENDED - PART II

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

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/176,298	07/05/2011	2473	1298	9147-99460-US	24	3

CONFIRMATION NO. 4342

UPDATED FILING RECEIPT

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

OC000000049201905

Date Mailed: 08/11/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Paul Howard, Briston, UNITED KINGDOM;

Assignment For Published Patent Application

WIRELESS TECHNOLOGY SOLUTIONS LLC, New York, NY

Power of Attorney: The patent practitioners associated with Customer Number 22242

Domestic Priority data as claimed by applicant

This application is a CON of 11/646,692 12/27/2006 PAT 8,009,639

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 07/14/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/176,298**

Projected Publication Date: 11/17/2011

Non-Publication Request: No

Early Publication Request: No

Title

Feedback Control in an FDD TDD-CDMA System

Preliminary Class

370

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

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The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. 13/176,298

Filed: July 5, 2011

Applicants: Paul Howard

Title: **FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM**

Art Unit: 2473

Examiner: Not Yet Assigned

Attorney Docket: 9147-99460-US

Customer No.: 22242

Confirmation No. 4342

This Letter Transmitting Corrected Application Data Sheet and Request for Updated Filing Receipt was electronically filed on August 25, 2011 using the U.S. Patent and Trademark Office's EFS Web

Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313-1450

ATTENTION: Office of Initial Patent Examination
Filing Receipt Corrections

LETTER TRANSMITTING CORRECTED APPLICATION DATA SHEET ALONG WITH REQUEST FOR CORRECTED FILING RECEIPT

Sir:

Please substitute the attached Application Data Sheet 37 CFR 1.76 for the document originally submitted with the filing of the application on July 5, 2011. This is being submitted to correct an inadvertent error in the inventor's Residence Address.

It is respectfully requested that the United States Patent and Trademark Office issue a corrected Updated Filing Receipt to incorporate the change herein requested (On page 1 of the Filing Receipt, Applicant(s), , please change "Briston" to -- Bristol --).

The Commissioner is hereby authorized to charge any additional fees which may be required with respect to this communication, or credit any overpayment, to Deposit Account No. 06-1135.

Respectfully submitted,

FITCH, EVEN, TABIN & FLANNERY

Dated: August 25, 2011

Steven G. Parmelee
Registration No. 28,790

120 South LaSalle Street, Suite 1600
Chicago, Illinois 60603-3406
Telephone (312) 577-7000
Facsimile (312) 577-7007

UNITED STATES PATENT AND TRADEMARK OFFICE

Docketed 08/12/11 pa #2 Helen

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

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/176,298	07/05/2011	2473	1298	9147-99460-US	24	3

CONFIRMATION NO. 4342

UPDATED FILING RECEIPT

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

OC000000049201905

Date Mailed: 08/11/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s) Bristol

Paul Howard, ~~Bristen~~, UNITED KINGDOM;

Assignment For Published Patent Application

WIRELESS TECHNOLOGY SOLUTIONS LLC, New York, NY

Power of Attorney: The patent practitioners associated with Customer Number 22242

Domestic Priority data as claimed by applicant

This application is a CON of 11/646,692 12/27/2006 PAT 8,009,639

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 07/14/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/176,298**

Projected Publication Date: 11/17/2011

Non-Publication Request: No

Early Publication Request: No

Title

Feedback Control in an FDD TDD-CDMA System

Preliminary Class

370

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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Title 37, Code of Federal Regulations, 5.11 & 5.15

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1 Remove

Applicant Authority ◉ Inventor ○ Legal Representative under 35 U.S.C. 117 ○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Paul		Howard	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Bristol	Country Of Residence[i]	UK
Citizenship under 37 CFR 1.41(b)[i]	UK		

Mailing Address of Applicant:

Address 1	Tennyson Cottage, Tennyson Road		
Address 2	Horfield		
City	Bristol	State/Province	
Postal Code	BS7 8SB	Country[i]	UK

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	22242		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	Feedback Control in an FDD TDD-CDMA System		
Attorney Docket Number	9147-99460-US	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	5	Suggested Figure for Publication (if any)	

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Approved for use through 06/30/2010. OMB 0651-0032
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	22242		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation of	11646692	2006-12-27

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

Remove

Application Number	Country [i]	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			○ Yes ◉ No

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.

Assignee 1 Remove

PTO/SB/14 (07-07)
Approved for use through 06/30/2010. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9147-99460-US
	Application Number	
Title of Invention	Feedback Control in an FDD TDD-CDMA System	

If the Assignee is an Organization check here. ☒			
Organization Name	Wireless Technology Solutions LLC		
Mailing Address Information:			
Address 1	550 Madison Avenue		
Address 2			
City	New York	**State/Province**	NY
Country [i]	US	Postal Code	10022
Phone Number		Fax Number	
Email Address			
Additional Assignee Data may be generated within this form by selecting the **Add** button.		Add	

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/Steven G. Parmelee/			Date (YYYY-MM-DD)	2011-08-25
First Name	Steven G.	Last Name	Parmelee	Registration Number	28790

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

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Electronic Acknowledgement Receipt

EFS ID:	10809726
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9147-99460-US
Receipt Date:	25-AUG-2011
Filing Date:	05-JUL-2011
Time Stamp:	10:00:21
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Corrected Filing Receipt	99460_Request_For_Filing_Receipt_1.PDF	235985 c4e66ba3a8be87591a138e89d288b357f3ebfdd4	no	5

Warnings:	
Information:	

2	Application Data Sheet	99460_Application_Data_Sheet.pdf	964779 fdb26c17089e998f5b4603fca993a8d20a93ca8f	no	4
Warnings:					
Information:					
			Total Files Size (in bytes):	1200764	

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

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

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/176,298	07/05/2011	2472	1298	9147-99460-US	24	3

CONFIRMATION NO. 4342

CORRECTED FILING RECEIPT

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

OC000000049560451

Date Mailed: 08/30/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Paul Howard, Bristol, UNITED KINGDOM;

Assignment For Published Patent Application

WIRELESS TECHNOLOGY SOLUTIONS LLC, New York, NY

Power of Attorney: The patent practitioners associated with Customer Number 22242

Domestic Priority data as claimed by applicant

This application is a CON of 11/646,692 12/27/2006 PAT 8,009,639

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 07/14/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/176,298**

Projected Publication Date: 11/17/2011

Non-Publication Request: No

Early Publication Request: No

Title

Feedback Control in an FDD TDD-CDMA System

Preliminary Class

370

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www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/176,298	07/05/2011	Paul Howard	9147-99460-US

CONFIRMATION NO. 4342

22242
FITCH EVEN TABIN & FLANNERY
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

PUBLICATION NOTICE



Title: Feedback Control in an FDD TDD-CDMA System

Publication No.US-2011-0280165-A1
Publication Date:11/17/2011

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	13176298
Filing Date	2011-07-05
First Named Inventor	Howard, Paul
Art Unit	2473
Examiner Name	Not Yet Assigned
Attorney Docket Number	9010-99460-US

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	5056109		1991-10-08	Gilhousen et al.	
	2	5265119		1993-11-23	Gilhousen et al.	
	3	5485486		1996-01-16	Gilhousen et al.	
	4	6061784		2000-05-09	Tarsky et al.	
	5	6567459		2003-05-20	Hakkinen et al.	
	6	6978151		2005-12-20	Choi et al.	
	7	7120134		2006-10-10	Tiedemann, Jr. et al.	
	8	7215657		2007-05-08	Toshimitsu et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Howard, Paul
	Art Unit	2473
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	9010-99460-US

	9	8009639		2011-08-30	Howard	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020075891		2002-06-20	Souissi	
	2	20020168993		2002-11-14	Choi et al.	
	3	20040152473		2004-08-05	Kuwano et al.	
	4	20040203419		2004-10-14	Crocker et al.	
	5	20060093026		2006-05-04	Montojo et al.	
	6	20060211417		2006-09-21	Pedlar	
	7	20070173256		2007-07-26	Laroia et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Howard, Paul
	Art Unit	2473
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	9010-99460-US

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	DE10201270	DE		2002-08-08	Samsung Electronics Co., Ltd.		☐
	2	EO1467582	EP		2004-10-13	Telefonaktiebolaget LM Ericsson		☐
	3	EP1615384	EP		2006-01-11	Qualcomm Incorporated		☐
	4	EP1681780	EP		2006-07-19	Fujitsu Limited		☐

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	1	"3 UMTS Interfaces," UMTS Protocols and Protocol Testing, pp. 9-14, located at <http://www.tek.com/Measurement/App.sub.--Notes/2F.sub.--14251/eng/int- erfaces.pdf>.	☐
	2	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Feasibility Study for Evolved UTRA and UTRAN (Release 7)," (Mar. 2006). 3GPP:Valbonne, France, TS 25.912 v0.0.4:1-13.	☐
	3	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; 3GPP System Architecture Evolution: Report on Technical Options and Conclusions (Release 7)," (Jul. 2005). 3GPP:Valbonne, France, TS 23.882 v0.3.0:1-13.	☐
	4	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; General UMTS Architecture (3G TS23.101 version 3.0.1)," (Apr. 1999). 3GPP:Valbonne, France, TS 23.101 v3.0.1:1-13.	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Howard, Paul
	Art Unit	2473
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	9010-99460-US

	5	"3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS); Architecture and Functional Description (Release 6); 3GPP: Valbonne, France; 3GPP TS 23.246 v.6.4.0 (2004-09);	☐
	6	"UMTS Protocols and Protocol Testing," Tektronix, The International Engineering Consortium, pp. 1-45, located at <http://www.rfpeople.com/docs/umts.pdf>.	☐
	7	Ghadialy, Z. "Tutorial: Medium Access Control (MAC) in 3G/UMTS Protocol Stack," located at <http://www.3g4g.co.uk/Tutorial/ZG/zg.sub.--mac.html> visited on Jun. 20, 2007. (9 pages).	☐
	8	International Engineering Consortium. "Universal Mobile Telecommunications System (UMTS) Protocols and Protocol Testing," located at <http://www.iec.org/online/tutorials/umts/topic02.html> visited on Jun. 20, 2007. (7 pages).	☐
	9	International Preliminary Report on Patentability issued on Jun. 30, 2009 from PCT Application No. PCT/EP20071064483.	☐

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

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

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☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/Steven G. Parmelee/	Date (YYYY-MM-DD)	2012-04-16
Name/Print	Steven G. Parmelee	Registration Number	28,790

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(19) BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENT- UND MARKENAMT

(12) **Offenlegungsschrift**

(10) **DE 102 01 270 A 1**

(51) Int. Cl.[7]:
H 04 J 3/16
H 04 B 7/204
// H04J 13/02,H04Q 7/20

(21) Aktenzeichen: 102 01 270.9
(22) Anmeldetag: 15. 1. 2002
(43) Offenlegungstag: 8. 8. 2002

DE 102 01 270 A 1

(30) Unionspriorität:
01-2131 15. 01. 2001 KR

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Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

Rechercheantrag gem. Paragraph 43 Abs. 1 Satz PatG ist gestellt

Prüfungsantrag gem. § 44 PatG ist gestellt

(54) Verfahren und Vorrichtung für das Steuern der Sendeleistung in einem NB-TDD CDMA Kommunikationssystem

(57) Ein TDD (Zeitduplex) CDMA (Vielfachzugriff durch Kodetrennung) Kommunikationssytem führt eine Leistungssteuerung in einer Leistungssteuerbetriebsart mit geschlossener Schleife in einer Datenübertragungszeitdauer durch, wobei sie aber die Leistungssteuerung unter Verwendung eines modifizierten Leistungssteuerverfahrens mit offener Schleife und eines Leistungssteuerverfahrens mit offener Schleife als auch das Leistungssteuerverfahren mit geschlossener Schleife in einer Übertragungspausenzeitdauer durchführt, um somit die anfängliche Übertragungsleistung nach dem Ende der Übertragungspausenzeitdauer passend einzustellen.

DE 102 01 270 A 1

Beschreibung

PRIORITÄT

[0001] Diese Anmeldung beansprucht die Priorität einer Anmeldung mit dem Titel "A Power Control Method in Narrow Band Time Division Duplexing Code Division Multiple Access Communication", die beim koreanischen Patentamt am 15. Januar 2001 eingereicht wurde, und der die Seriennummer 2001-2131 zugewiesen wurde, wobei der Inhalt dieser Anmeldung hiermit durch Bezugnahme eingeschlossen wird.

HINTERGRUND DER ERFINDUNG

GEBIET DER ERFINDUNG

[0002] Die vorliegende Erfindung betrifft allgemein NB-TDD (Narrow Band Time Division Duplexing, schmalbandige Zeitduplexsysteme) CDMA (Vielfachzugriff durch Kodetrennung) Kommunikationssysteme und insbesondere eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung beim Auftreten einer Übertragungspause.

BESCHREIBUNG DES STANDS DER TECHNIK

[0003] Im allgemeinen kann eine dritte Generation der mobilen Kommunikationssysteme als FDD-Kommunikationssysteme (Frequency Division Duplexing Kommunikationssysteme), die sich bei der Übertragung in Aufwärtsrichtung in der Frequenz von der Übertragung in Abwärtsrichtung unterscheiden, und als WB/NB-TDD (Wide Band/Narrow Band Time Division Duplexing, Breitband/Schmalband, Zeitduplex) Kommunikationssysteme, die die Übertragung in Aufwärtsrichtung von der Übertragung in Abwärtsrichtung auf der Zeitbasis trennen, klassifiziert werden. Das WB-TDD Kommunikationssystem und das FDD-Kommunikationssystem verwendet eine Chiprate von 3,48 MHz, während das NB-TDD-Kommunikationssystem eine Chiprate von 1,28 MHz verwendet.

[0004] Im NB-TDD-Kommunikationssystem wird eine Kommunikation zwischen einer UE (Benutzerausrüstung) und einem Knoten B durch einen Kanal, der zwischen ihnen angeordnet ist, durchgeführt. Da die Daten diskontinuierlich (oder als Impulsfolge) durch den Kanal auf einer Zeitmultiplexbasis übertragen werden, kann es sein, daß lange Übertragungspausen auftreten. Somit kann es sein, daß wenn ein Übertragungssignal in Aufwärtsrichtung oder Abwärtsrichtung nach jeder Übertragungspause übertragen wird, daß sich seine anfängliche Übertragungsleistung durch die Übertragungspause nicht auf einem passenden Pegel befindet.

[0005] Wie oben angegeben wurde, umfaßt die dritte Generation eines asynchronen mobilen Kommunikationssystems, die eine Zeitmultiplextechnik verwendet, das WB-TDD-System und das NB-TDD-System. Ein Hauptunterschied zwischen dem WB-TDD-System und dem NB-TDD-System liegt in einer Chiprate: das WB-TDD-System verwendet eine Chiprate von 3,48 MHz, während das NB-TDD-System eine Chiprate von 1,28 MHz verwendet. Weiterhin verwendet das WB-TDD-System und das NB-TDD-System ein Leistungssteuerverfahren für eine Übertragung in Aufwärtsrichtung/Abwärtsrichtung für das maximale Steuern der Interferenzen zwischen den UEs im Knoten B und den Interferenzen zu einem anderen Knoten B. Ein Unterschied in einem Übertragungsleistungssteuerverfahren zwischen dem WB-TDD-System und dem NB-TDD-System wird nachfolgend hier beschrieben.

[0006] Zuerst erfolgt eine Beschreibung eines Übertragungsleistungssteuerverfahrens für das WB-TDD-Kommunikationssystem.

[0007] Das WB-TDD-Kommunikationssystem verwendet ein Leistungssteuerverfahren mit offener Schleife für die Übertragungsleistungssteuerung in Aufwärtsrichtung, und ein Leistungssteuerverfahren mit geschlossener Schleife für eine Übertragungsleistungssteuerung in Abwärtsrichtung. Im Leistungssteuerverfahren mit offener Schleife, das für das Steuern der Übertragungsleistung einer UE in einem WB-TDD-Kommunikationssystem in Aufwärtsrichtung verwendet wird, mißt die UE einen Ausbreitungsverlust eines primären gemeinsamen physikalischen Steuerkanals (P-CCPCH), der von einem Knoten B übertragen wird, und steuert passend seine Aufwärtsübertragungsleistung auf der Basis des gemessenen Ausbreitungsverlusts, so daß der Knoten B ein Kanalsignal, das durch die UE gesendet wird, korrekt empfangen kann. Hier dient der P-CCPCH als ein Kanal für das Übertragen der Information des Knotens B und der Systeminformation (SI) an die UEs im Knoten B. Der P-CCPCH wird mit einer konstanten Übertragungsleistung übertragen, und ein Übertragungsleistungspegel des P-CCPCH wird an die UEs im Konten B übertragen. Die UE kann den Ausbreitungsverlust vom Knoten B unter Verwendung der Übertragungsinformation auf dem Übertragungsleistungspegel des P-CCPCH messen. Weiterhin empfängt im Leistungssteuerverfahren mit geschlossener Schleife, das für das Steuern der Übertragungsleistung in Abwärtsrichtung des Knotens B im WB-TDD-Kommunikationssystem verwendet wird, die UE ihr Signal vom Knoten B, und mißt dann einen Pegel (oder ein Signal-zu-Interferenz-Verhältnis (SIR)) des empfangenen Signals. Wenn der Pegel des Signals, das vom Knoten B empfangen wurde, kleiner als ein vorbestimmter Schwellwert ist, so überträgt die UE einen TPC-Befehl (Übertragungsleistungsbefehl), der den Knoten B anweist, seine Übertragungsleistung zu erhöhen. Im Gegensatz dazu sendet, wenn der Pegel des Signals, das vom Knoten B empfangen wird, höher oder gleich dem Schwellwert ist, die UE einen TPC-Befehl, der den Knoten B anweist, seine Übertragungsleistung zu erniedrigen. Der Knoten B steuert dann die Übertragungsleistung in Abwärtsrichtung auf der Basis des TPC-Befehls, der von der UE empfangen wurde, so daß die Übertragungsleistung, die von der UE empfangen wurde, einen konstanten Pegel aufweisen kann. Dieses Verfahren wird als das "Leistungssteuerverfahren mit geschlossener Schleife" bezeichnet. Mit anderen Worten, das WB-TDD-Kommunikationssystem, wie es oben angegeben wurde, verwendet das Leistungssteuerverfahren mit geschlossener Schleife für die abwärtige Übertragungsleistungssteuerung und das Leistungssteuerverfahren mit offener Schleife für die Übertragungsleistungssteuerung in Aufwärtsrichtung.

[0008] Im Gegensatz zum WB-TDD-Kommunikationssystem spezifiziert das 3GPP (Partnerschaftsprojekt der dritten Generation) TSG (Technical Special Group) RAN (Radio Access Network) TR (Technical Report), daß das NB-TDD-Kommunikationssystem das Leistungssteuerverfahren mit geschlossener Schleife sowohl für die Übertragungsleistungssteuerung in Aufwärtsrichtung als auch für die Übertragungsleistungssteuerung in Abwärtsrichtung verwendet. Ein Hauptunterschied zwischen dem Leistungssteuerverfahren mit offener Schleife und dem Leistungssteuerverfahren mit geschlossener Schleife besteht darin, ob der TPC-Befehl übertragen werden soll oder nicht. Im WB-TDD-Kommunikationssystem wird, da das Leistungssteuerverfahren mit geschlossener Schleife nur für die Übertragung in Abwärtsrichtung verwendet wird, der TPC-Befehl nur durch die

Aufwärtsverbindung übertragen. Im NB-TDD-Kommunikaitonssystem wird jedoch, da das Leistungssteuerverfahren sowohl für die Übertragungen in Aufwärtsrichtung als auch in Abwärtsrichtung verwendet wird, der TPC-Befehl sowohl durch die Aufwärtsverbindung als auch die Abwärtsverbindung übertragen.

[0009] Als nächstes wird eine Aufwärtsverbindung/Abwärtsverbindung-Übertragungsleistungssteuerverfahren für das NB-TDD-System hier unter Bezug auf **Fig.** 1 beschrieben.

[0010] **Fig.** 1 zeigt eine Struktur eines Unterrahmens eines NB-TDD-Kommunikationssystems. Wenn man **Fig.** 1 betrachtet, weist ein Unterrahmen eine Länge von 5 ms auf, und zwei Unterrahmen bilden einen Rahmen. Somit weist der Rahmen eine Länge von 10 ms auf, und er wird zu einem Funkrahmen, einer Grundfunkübertragungseinheit im mobilen Kommunikationssystem der dritten Generation. Der 10 ms Funkrahmen wird zu einer Grundfunkübertragungseinheit, die gemeinhin in den FDD, WB-TDD und NB-TDD Kommunikationssystemen verwendet wird.

[0011] Der Unterrahmen besteht aus sieben Zeitschlitzen TS0-Ts6, einem Pilotzeitschlitz in Abwärtsrichtung (DwPTS oder Pilotkanal in Abwärtsrichtung (DwPCH)) **102**, einem Pilotzeitschlitz in Aufwärtsrichtung (UpPTS oder Pilotkanal in Aufwärtsrichtung (UpPCH)) **104**, und eine Schutzperiode (GP) **103**. Von den Zeitschlitzen TS0–TS6 sind die Zeitschlitze TS0 und TS4–TS6, die durch Abwärtspfeile dargestellt sind, Zeitschlitze in Abwärtsrichtung, die vom Knoten B zur UE übertragen werden, während die Zeitschlitze TS1–TS3, die durch Aufwärtspfeile dargestellt werden, Zeitschlitze in Aufwärtsrichtung sind, die von der UE zum Knoten B übertragen werden. Da das NB-TDD-Kommunikationssystem von der Übertragung in Aufwärtsrichtung zur Übertragung in Abwärtsrichtung und umgekehrt in einer Zeitschlitzeinheit umschaltet, so weist es die Zeitschlitze des Unterrahmens für die Übertragung in Aufwärtsrichtung und die Übertragung in Abwärtsrichtung gemäß den folgenden Regeln zu.

[0012] In der Unterrahmenstruktur muß der erste Zeitschlitz (TS0) **101** fest für die Übertragung in Abwärtsrichtung verwendet werden, und der DwPTS **102** ist eine Zeitdauer, während der der Knoten B eine vorbestimmte Kodesequenz zur UE überträgt, so daß die UE eine Synchronisation in Abwärtsrichtung erwerben kann. Der UpPTS **104** ist eine Zeitdauer, während der die UE eine vorbestimmte Kodesequenz zum Knoten B für die Synchronisation in Aufwärtsrichtung überträgt. Weiter stellt ein Schaltpunkt (SP) **110** einen Punkt da, wo die Übertragung in Abwärtsrichtung geschaltet wird. Die GP **103** ist eine Zeitdauer, während derer keine Übertragung stattfindet, wobei sie errichtet wurde, um eine Interferenz zwischen dem DwPTS **102** und dem UpPTS **104** durch eine mögliche Überlappung zwischen ihnen zu verhindern. Ein Schaltpunkt **111** ist ein Zeitpunkt für das Trennen der Übertragung in Aufwärtsrichtung von der Übertragung in Abwärtsrichtung der Zeitschlitze, bei denen es sich nicht um den ersten Zeitschlitz (TS0) **101** handelt. Hier wird der Schaltpunkt **111** variabel eingestellt, so daß die Anzahl der Schlitze in Aufwärtsrichtung größer als die Anzahl der Schlitze in Abwärtsrichtung ist, wenn eine größere Menge der Übertragungsdaten in Aufwärtsrichtung vorhanden ist, während die Anzahl der Schlitze in Abwärtsrichtung größer ist als die Anzahl der Schlitze in Aufwärtsrichtung, wenn eine größere Menge der Übertragungsdaten in Abwärtsrichtung vorhanden ist.

[0013] **Fig.** 2 zeigt ein Verfahren für das Zuweisen der Kanäle in Aufwärtsrichtung/Abwärtsrichtung an die UEs durch einen Konten B im NB-TDD-Kommunikationssystem. Aus Gründen der Einfachheit wird in **Fig.** 2 angenommen, daß ein Knoten B einen Kanal in Aufwärtsrichtung/Abwärtsrichtung einer UE zuweist. Betrachtet man die **Fig.** 2, so sind dort ein erster Funkrahmen **201**, ein zweiter Funkrahmen **202**, eine (K–1)-ter Funkrahmen **203** und ein K-ter Funkrahmen **204** gezeigt. Jeder Funkrahmen besteht aus zwei Unterrahmen. Das heißt, der erste Funkrahmen **201** besteht aus einem ersten Unterrahmen **211** und einem zweiten Unterrahmen **212**; der zweite Funkrahmen **202** besteht aus einem ersten Unterrahmen **221** und einem zweiten Unterrahmen **222**; der (K–1)-te Funkrahmen **203** besteht aus einem ersten Unterrahmen **231** und einem zweiten Unterrahmen **232**; und der K-te Funkrahmen **204** besteht aus einem ersten Unterrahmen **241** und einem zweiten Unterrahmen **242**.

[0014] In **Fig.** 2 informiert, wenn die UE eine Kanalzuweisungsanforderung an den Knoten B sendet, oder der Knoten B aufgefordert wird, einen Kanal an die UE zuzuweisen, der Knoten B die UE über solche Ressourcen, wie den Funkrahmen, den Unterrahmen, den Zeitschlitz und den Kanaleinteilungskode, der für die Übertragung in Abwärtsrichtung verwendet werden soll. Von den Ressourcen, die für die Kanalzuweisung verwendet werden, ist der Kanaleinteilungskode ein orthogonaler Kode. Bei der Übertragung in Abwärtsrichtung dient der orthogonale Kode dazu, einen Transportkanal in Abwärtsrichtung, der einer spezifische UE zugewiesen ist, von den Kanälen in Abwärtsrichtung, die anderen UEs zugewiesen sind, und die denselben Zeitschlitz verwenden, zu unterscheiden, indem unterschiedliche orthogonale Kodes den jeweiligen UEs zugewiesen werden. Für die Übertragung in Aufwärtsrichtung verwendet der Knoten B ortohogonale Kodes bei der Identifizierung der unterschiedlichen UEs, die denselben Zeitschlitz verwenden. Natürlich können für die Übertragung in Aufwärtsrichtung/Abwärtsrichtung durch den Orthogonalkode zwei oder mehr unterschiedliche Orthogonalkodes derselben UE zugewiesen werden, um eine Datenrate der Übertragung in Abwärtsrichtung zur UE und die Übertragung in Aufwärtsrichtung von der UE zu erhöhen. Weiterhin wird ein OVSF-Kode (Orthogonal Variable Spreading Factor), der in den asynchronen mobilen Kommunikationssystemen verwendet wird, typischerweise für den Kanaleinteilungskode, der im NB-TDD Kommunikationssystem verwendet wird, verwendet. Hier ist der OVSF-Kode dadurch gekennzeichnet, daß seine Länge gemäß einem Spreizungsfaktor (SF) für eine Datenspreizung variabel ist. Wenn beispielsweise der Spreizungsfaktor 4 ist (SF = 4), so wird ein Datenband um das Vierfache erweitert.

[0015] In diesem Fall wird die Länge des verwendeten Kanalzuteilungskodes 4, und es werden 4 verfügbare (SF = 4) Kanalzuteilungskodes erzeugt. Die Datenspreizfaktoren, die im NB-TDD-Kommunikationssystem verwendet werden, sind 1, 2, 4, 8 und 16, und wenn der Spreizungsfaktor mehr und mehr zunimmt, so nimmt die Datenrate der Übertragungsdaten ab.

[0016] In **Fig.** 2 besteht ein Verfahren für die Bestimmung von Kanälen in Aufwärtsrichtung/Abwärtsrichtung zwischen dem Knoten B und der UE darin, einen Kanal in Abwärtsrichtung mit einigen der Zeitschlitze, die für die Übertragung in Abwärtsrichtung verwendet werden, unter den Zeitschlitzen des Unterrahmens **211**, und einen spezifischen Kanalzuteilungskode zu errichten, und darin, einen Kanal in Aufwärtsrichtung mit einigen der Zeitschlitze, die für die Übertragung in Aufwärtsrichtung unter den Zeitschlitzen des Unterrahmens **211** verwendet werden, und einen spezifischen Kanalzuteilungskode zu errichten. Die Kanäle in Abwärtsrichtung/Aufwärtsrichtung (Zeitschlitze und Kanalzuteilungskodes), die zwischen der UE und dem Knoten B errichtet sind, werden wiederholt in einer Funkrahmeneinheit

verwendet, und wenn es notwendig ist, so können die Kanäle in Aufwärtsrichtung/Abwärtsrichtung (Zeitschlitze und Kanalzuteilungskodes) zwischen der UE und dem Knoten B wieder errichtet werden. Eine Wiederholungsperiode der Kanäle in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B und dieAnzahl der Funkrahmen, nachdem eine Wiedererrichtung durchgeführt werden soll, kann vom Typ und der Menge der Daten, die zwischen der UE und dem Knoten B ausgetauscht werden, abhängen. Zusätzlich kann, wenn die Menge der Übertragungsdaten in Aufwärtsrichtung größer ist als die Menge der Übertragungsdaten in Abwärtsrichtung der Transportkanal in Aufwärtsrichtung häufiger als der Transportkanal in Abwärtsrichtung wiederholt werden. In **Fig.** 2 ist der K-te Rahmen **204** ein Rahmen, bei dem der Datenaustausch zwischen der UE und dem Knoten B endet.

[0017] **Fig.** 3 zeigt eine typische Struktur eines Zeitschlitzes in einem Unterrahmen. Die in **Fig.** 3 dargestellte Zeitschlitzstruktur kann sowohl für eine Übertragung in Aufwärtsrichtung als auch in Abwärtsrichtung verwendet werden. Die Datensymbole **311** und **317** werden für eine Übertragung von Übertragungsdaten in Aufwärtsrichtung und in Abwärtsrichtung verwendet, und TFCIs (Transport Format Combination Indicators, Transportformatkombinationsindikatoren) **312** und **316** dienen dazu, eine Datenrate eines Kanals in Abwärtsrichtung vom Knoten B zur UE oder Datenraten der Kanalzuteilungskodes für die Übertragung eines Kanals in Abwärtsrichtung den den Typ der Daten anzuzeigen. Weiterhin haben für den Kanal in Aufwärtsrichtung die TFCIs dieselbe Funktion wie beim Kanal in Abwärtsrichtung. Eine Mitambel **313** wird verwendet, um UEs, die denselben Zeitschlitz verwenden, zu identifizieren, oder um Kanäle in Abwärtsrichtung, die denselben Zeitschlitz in den WB-TDD und NB-TDD Kommunikationssystemen verwenden, zu identifizieren. Weiterhin wird für die Übertragungen in Aufwärtsrichtung/Abwärtsrichtung die Mitambel **313** für eine Kanalschätzung verwendet, und für die Übertragung in Abwärtsrichtung werden verschiedene Mitambels verwendet, um einen Verlust der Kanalausbreitung vom Knoten B zur UE zu messen. Alternativ kann der Knoten Bs verschiedene Mitambels für die Identifikation des Knotens Bs verwenden. Es wird eine spezielle Sequenz für die Mitambel **313** verwendet, und die Anzahl der speziellen Sequenzen, die für die Mitambel verwendet werden, beträgt 128. Die Kanalzuteilungskodes und die Mitambelsequenzen, die unter Bezug auf **Fig.** 2 beschrieben werden, weisen unterschiedliche Eigenschaften und Typen auf, und dies wird für eine Übertragung in Aufwärtsrichtung unter Bezug auf **Fig.** 3 beschrieben. Für die Übertragung in Aufwärtsrichtung wird der Kanalzuteilungskode, wie ein orthogonaler Kode, für die Datensymbole **311** und **317** verwendet, und er dient dazu, Daten von den UEs, die mit den Datensymbolen **311** und **317** übertragen werden, zu unterscheiden. Eine Mitambel **313** dient zur Identifizierung, welche UE Daten überträgt, und die Mitambel **313** ist kein Subjekt der Bandausdehnung mit einem Kanalzuteilungskode.

[0018] Zusätzlich wird eine SS (Synchronization Shift, Synchronisationsverschiebung) **314** verwendet, um einen Synchronisationssteuerbefehl zu übertragen, wenn die Synchronisation zwischen der UE und dem Knoten B durch eine Änderung in der Distanz zwischen der UE und dem Knoten B während der Signalübertragung oder durch andere Gründe mißlungen ist. In Erwiderung auf den Befehl, der durch die SS **314** übertragen wurde, kann die UE einen Übertragungspunkt in einer %-Chip-Einheit steuern. Weiterhin ist die GP **318** eine Periode für das Trennen des aktuellen Zeitschlitzes vom nächsten Zeitschlitz. Die GP **318** dient als ein Schutz, um Interferenzen zwischen einem Signal in Aufwärtsrichtung und einem Signal in Abwärtsrichtung zu verhindern, wenn das Übertragungsschlitzsignal in Abwärtsrichtung in der Übertragungsschlitzperiode der Aufwärtsrichtung empfangen wird, oder wenn das Übertragungsschlitzsignal in Aufwärtsrichtung in der Übertragungsschlitzperiode der Abwärtsrichtung empfangen wird. Schließlich wird der TPC-Befehl (Übertragungsleistungssteuerbefehl) **315** für das Steuern einer Übertragungleistung des Knotens B in Abwärtsrichtung verwendet, wenn er durch die Aufwärtsverbindung übertragen wird, und der TPC **315** wird für das Steuern der Übertragungsleistung in Aufwärtsrichtung der UE verwendet, wenn er durch die Abwärtsverbindung übertragen wird. Hier wird ein Verfahren für das Bestimmen des TPC-Befehls **315** und das anschließende Übertragen des bestimmten TPC-Befehls für die Leistungssteuerung der Übertragung in Aufwärtsrichtung und die Leistungssteuerung der Übertragung in Abwärtsrichtung getrennt beschrieben.

Leistungssteuerung der Übertragung in Aufwärtsrichtung

[0019] Im Leistungssteuerverfahren für die Übertragung in Aufwärtsrichtung empfängt der Knoten B Daten, die von der UE durch die Aufwärtsverbindung übertragen werden, korrekt, indem ein Pegel der Leistung der Übertragung in Aufwärtsrichtung, die durch die UE übertragen wird, gesteuert wird, und er steuert die Leistung der Übertragung in Aufwärtsrichtung so, daß die empfangenen Daten nicht als Interferenz zu einem Signal wirken, das von einer anderen UE zum Knoten B durch einen übermäßig hohen Pegel der Übertragungsleistung der UE übertragen wird. Im NB-TDD Kommunikationssystem mißt der Knoten B für die Leistungssteuerung der Übertragung in Aufwärtsrichtung ein Signal-zu-Interferenz-Verhältnis (SIR) eines Signals, das über einen zugewiesenen physikalischen Kanal (DPCH) durch die UE übertragen wird, und vergleicht den gemessenen SIR-Wert mit einem vorbestimmten SIR-Wert (SIR_{Ziel}). Um die Daten, die über den zugewiesenen Kanal der UE in Aufwärtsrichtung übertragen werden, korrekt zu empfangen, überträgt der Knoten B einen Übertragungsleistungsabschaltbefehl an die UE in Abwärtsrichtung, wenn der gemessene SIR-Wert größer als oder gleich dem SIR-Zielwert ist. Wenn der gemessene SIR-Wert kleiner als der SIR-Zielwert ist, so überträgt der Knoten B einen Übertragungsleistungserhöhungsbefehl an die UE. Weiter ist der DPCH ein physikalischer Kanal für das Übertragen von Benutzerdaten und Signalisierungsinformation von einer oberen Lage, und er wird nur durch die UE, die durch den Knoten B bezeichnet ist, verwendet, und die anderen UEs teilen nicht den DPCH, der einer spezifischen UE zugewiesen ist.

Leistungssteuerung der Übertragung in Abwärtsrichtung

[0020] Im Leistungssteuerverfahren der Übertragung in Abwärtsrichtung steuert die UE die Übertragungsleistung eines Signals vom Knoten B n Abwärtsrichtung, so daß die UE das Signal in Abwärtsrichtung korrekt und ohne Fehler empfangen kann. Das Leistungssteuerverfahren der Übertragung in Abwärtsrichtung wird in derselben Weise wie das Leistungssteuerverfahren der Übertragung in Aufwärtsrichtung durchgeführt. Das heißt, die UE mißt ein SIR eines DPCH-Signals in Abwärtsrichtung vom Knoten B und vergleicht den gemessenen SIR-Wert mit einem vorbestimmten SIR-Zielwert. Wenn als Ergebnis des Vergleichs der gemessene SIR-Wert kleiner als der SIR-Zielwert ist, überträgt die UE einen Übertragungsleistungserhöhungsbefehl in Aufwärtsrichtung an den Knoten B. Sonst überträgt, wenn der gemessene SIR-Wert größer oder gleich dem SIR-Zielwert ist, die UE einen Übertragungsleistungsabsenkbefehl in

Aufwärtsrichtung zum Knoten B, so daß der Knoten B die Übertragungsleistung eines Signals, das zur UE übertragen wird, steuert.

[0021] Wie in Bezug auf die **Fig.** 2 und 3 beschrieben wurde, so wird im NB-TDD Kommunikationssystem ein zugewiesener Kanal zwischen dem Knoten B und der UE durch den Zeitschlitz, den Kanalzuweisungkode und den Funkrahmen zugewiesen, und der TPC-Befehl wird in einer Unterrahmeneinheit übertragen. Im NB-TDD-Kommunikationssystem beträgt, wenn die Kanäle in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B in jedem Unterrahmen errichtet sind, die maximale Frequenz der Übertragung der TPC-Befehle in Aufwärtsrichtung/Abwärtsrichtung 200 Hz; wenn die Kanäle in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B in jedem Funkrahmen errichtet sind, so beträgt die maximale Frequenz der Übertragung 100 Hz; und wenn die Kanäle in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B alle 10 Funkrahmen errichtet werden, so beträgt die maximale Frequenz der Übertragungen 10 Hz. Weiter kann es sein, daß im NB-TDD Kommunikationssystem die Kanäle in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B nicht gleichmäßig errichtet werden: die Frequenz der Errichtung des Übertragungszeitschlitzes in Aufwärtsrichtung wird erhöht, wenn eine größere Menge der Übertragungsdaten in Aufwärtsrichtung vorliegen, und die Frequenz der Errichtung des Übertragungsschlitzes in Abwärtsrichtung wird erhöht, wenn eine größere Menge von Übertragungsdaten in Abwärtsrichtung vorhanden sind. Somit kann es sein, daß die Frequenz der Übertragung des TPC-Befehls in Aufwärtsrichtung nicht gleich der Frequenz der Übertragung des TPC-Befehls in Abwärtsrichtung ist.

[0022] Somit ist das NB-TDD Kommunikationssystem, das nur das Leistungssteuerverfahren mit geschlossener Schleife für die Übertragungsleistungssteuerung der DPCH verwendet, bei der passenden Einstellung der Übertragungsleistung in Aufwärtsrichtung/Abwärtsrichtung im oben angegeben Zustand, das heißt in einer Situation, bei der die Kanäle in Aufwärtsrichtung/Abwärtsrichtung für die Übertragungen in Aufwärtsrichtung/Abwärtsrichtung zwischen der UE und dem Knoten B ungleichmäßig errichtet oder diskontinuierlich errichtet werden, ineffizient, was eine glatte Übertragung der TPC-Befehle stört.

[0023] Zusätzlich liefert das NB-TDD Kommunikationssystem einen gemeinsamen Kanal zusätzlich zum DPCH als einen Kanal für das Übertragen von Benutzerdaten oder Signalisierinformation einer oberen Lage, und der gemeinsame Kanal ist gleich dem DPCH in einer physikalischen Struktur und einem Übertragungsleistungssteuerverfahren. Der gemeinsame Kanal wird in einen gemeinsamen Kanal in Abwärtsrichtung (DSCH) und einen gemeinsamen Kanal in Aufwärtsrichtung (USCH) klassifiziert. Insbesondere kann der gemeinsame Kanal wirksam für einen Paketdatendienst verwendet werden. Im Gegensatz zum zugewiesenen Kanal wird der gemeinsame Kanal durch eine Vielzahl von UEs durch das gemeinsame Nutzen der Funkressourcen (beispielsweise dem Kanalzuteilungskode, dem Zeitschlitz und der Mitambel) genutzt. Die Paketdaten werden auf einer Impulsfolgenbasis (in Form einer Impulsfolge) unter Berücksichtigung ihrer Eigenschaft erzeugt, und die Paketdaten können diskontinuierlich unter Verwendung des gemeinsamen Kanals übertragen werden, da er gegen eine Übertragungszeitverzögerung nicht empfindlich ist. Somit kann es sein, daß in dem Fall, bei dem die Übertragungsleistung des gemeinsamen Kanals im Leistungssteuerverfahren mit der geschlossenen Schleife wie beim DPCH gesteuert wird, eine Periode für das Übertragen des TPC-Signals nicht während einer langen Zeit existiert, wenn eine Periode zwischen den Datenblöcken, während derer keine Übertragung erfolgt, erhöht wird, so daß es sein kann, daß die Daten nicht normal übertragen werden.

ZUSAMMENFASSUNG DER ERFINDUNG

[0024] Eine Aufgabe der vorliegenden Erfindung besteht somit darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines zugewiesenen physikalischen Kanals in einem NB-TDD-Kommunikationssystem bereit zu stellen.

[0025] Eine andere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines gemeinsamen Kanals in einem NB-TDD-Kommunikationssystem bereit zu stellen.

[0026] Eine weitere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung in Aufwärtsrichtung/Abwärtsrichtung nach dem Auftreten einer Übertragungspause, in der keine Daten übertragen werden, bereit zu stellen.

[0027] Eine nochmals andere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines zugewiesenen Kanals und eines gemeinsamen Kanals unter Verwendung eines Leistungssteuerverfahrens mit geschlossener Schleife in einem NB-TDD Kommunikationssystem bereit zu stellen.

[0028] Eine nochmals andere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines zugewiesenen Kanals und eines gemeinsamen Kanals unter Verwendung eines Leistungssteuerverfahrens mit offener Schleife zusammen mit einem Leistungssteuerverfahren mit einer geschlossener Schleife in einem NB-TDD Kommunikationssystem bereit zu stellen.

[0029] Eine nochmals andere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines zugewiesenen physikalischen Kanals unter Verwendung eines Steuerverfahrens mit geschlossener Schleife in einem NB-TDD Kommunikationssystem unter Verwendung einer Strahlformungstechnik bereit zu stellen.

[0030] Eine nochmals andere Aufgabe der vorliegenden Erfindung besteht darin, eine Vorrichtung und ein Verfahren für das Steuern der Übertragungsleistung eines zugewiesenen physikalischen Kanals und eines gemeinsamen physikalischen Kanals unter Verwendung eines Leistungssteuerverfahrens mit offener Schleife zusammen mit einem Leistungssteuerverfahren mit geschlossener Schleife in einem NB-TDD Kommunikationssystem, das eine Strahlformungstechnik unterstützt, bereit zu stellen.

[0031] Um die obigen Aufgaben und andere Aufgaben zu lösen, wird eine Übertragungsleistungssteuervorrichtung in einer UE für ein TDD CDMA Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder der Rahmen ein Feld, das die Leistungspegelinformation, die vom Knoten B übertragen wird, anzeigt, und ein Zeitschlitzfeld für das zuweisen eines TPC-Befehls und von Übertragungsdaten vom Knoten B zur UE einschließt, wobei die UE Daten empfängt, die vom Knoten B übertragen werden, die einem Zeitschlitzfeld in einem folgenden Rahmen nach einer Übertragungspausenzeitdauer, in der keine Daten in den Zeitschlitzfeldern existieren, in speziellen Rahmen unter dem Strom von Rahmen, der vom Knoten B zur UE übertragen wird, zugewiesen werden. Nach dem Auftreten einer Übertragungspause eines speziel-

len Kanalsignals, das vom Knoten B empfangen wird, mißt eine Übertragungsleistungssteuervorrichtung für die Aufwärtsrichtung einen Ausbreitungsverlust zwischen dem Knoten B und der UE auf der Basis der Leistungspegelinformation, die im speziellen Zeitschlitz in der Übertragungspausenzeitdauer empfangen wird, detektiert ein Interferenzrauschen des Knotens B vom spezifischen Kanalsignal, und bestimmt eine Übertragungsleistung in Aufwärtsrichtung durch das Aufsummieren (i) von Werten, die durch das Anlegen eines Gewichts, basierend auf der Länge der Übertragungspausenzeitdauer, auf den aktuell gemessenen Ausbreitungsverlust und einen mittleren Ausbreitungsverlust zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer bestimmt werden, (ii) eines vorbestimmten Ziel-SIR, und (iii) eines Versatzes für das Kompensieren des Ausbreitungsverlustfehlers. Ein TPC-Befehlsgenerator für die Abwärtsrichtung erzeugt einen TPC-Befehl für die Abwärtsrichtung für das Steuern der Übertragungsleistung in Abwärtsrichtung, die vom Knoten B im folgenden Rahmen übertragen werden soll, durch das Empfangen der Übertragungsleistung in Aufwärtsrichtung, die durch die Übertragungsleistungssteuervorrichtung in Aufwärtsrichtung bestimmt wird. Ein Multiplexer multiplext den TPC-Befehl für die Abwärtsrichtung, die Benutzerdaten, die zum Knoten B übertragen werden sollen, und einen TFCI, der einen Typ und eine Datenrate der Benutzerdaten anzeigt. Ein Multiplizierer multipliziert das Kanalsignal in Aufwärtsrichtung mit einer Kanalverstärkung, basierend auf der bestimmten Übertragungsleistung in Aufwärtsrichtung.

[0032] Um weiter die obige Aufgabe und andere Aufgaben zu lösen, wird ein Übertragungsleistungssteuerverfahren in einer UE für ein TDD CDMA Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder der Rahmen ein Feld, das die Leistungspegelinformation, die vom Knoten B übertragen wird, und ein Zeitschlitzfeld für das Zuweisen eines TPC-Befehls und von Übertragungsdaten vom Knoten B zur UE einschließt, worin die UE Daten empfängt, die vom Knoten B übertragen werden, die einem Zeitschlitzfeld im folgenden Rahmen nach einer Übertragungspausenzeitdauer, bei der keine Übertragungsdaten in den Zeitschlitzfeldern in speziellen Rahmen unter dem Strom der Rahmen, die vom Knoten B zur UE übertragen werden, zugewiesen sind, bereit gestellt. Das Verfahren umfaßt das Messen eines Ausbreitungsverlusts zwischen dem Knoten B und der UE durch das Empfangen der Leistungspegelinformation in einem spezifischen Zeitschlitz in der Übertragungspausenzeitdauer, das Messen eines Interferenzrauschens des Knotens B durch das Empfangen eines spezifischen Kanalsignals, das durch den Knoten B übertragen wird, und das Bestimmen einer Übertragungsleistung in Aufwärtsrichtung durch das Summieren von (i) Werten, die durch das Anwenden eines Gewichts, basierend auf einer Länge der Übertragungspausenzeitdauer, auf den aktuell gemessenen Ausbreitungsverlust und einen mittleren Ausbreitungsverlust zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer, bestimmt werden, (ii) eines vorbestimmten Ziel-Signal-zu-Interferenz-Verhältnisses (SIR), und (iii) eines Versatzes für das Kompensieren des Ausbreitungsverlustfehlers, und das Übertragen eines TPC-Befehls, der der bestimmten Übertragungsleistung in Aufwärtsrichtung entspricht, an den Knoten B.

KURZE BESCHREIBUNG DER ZEICHNUNGEN

[0033] Die obige und andere Aufgaben, Merkmale und Vorteile der vorliegenden Erfindung werden aus der folgenden detaillierten Beschreibung in Verbindung mit den begleitenden Zeichnungen deutlicher.

[0034] **Fig.** 1 zeigt eine Struktur eines Unterrahmens eines NB-TDD Kommunikationssystems;

[0035] **Fig.** 2 zeigt ein Verfahren für das Zuweisen von Kanälen in Aufwärtsrichtung/Abwärtsrichtung an UEs durch einen Knoten B im NB-TDD Kommunikationssystem;

[0036] **Fig.** 3 zeigt eine typische Struktur eines Zeitschlitzes im Unterrahmen;

[0037] **Fig.** 4 zeigt eine Struktur eines UE-Transceivers gemäß einer Ausführungsform der vorliegenden Erfindung;

[0038] **Fig.** 5 zeigt eine Struktur eines Transceivers des Knotens B gemäß einer Ausführungsform der vorliegenden Erfindung;

[0039] **Fig.** 6 zeigt ein Betriebsverfahren der UE gemäß einer Ausführungsform der vorliegenden Erfindung; und

[0040] **Fig.** 7 zeigt ein Betriebsverfahren des Knotens B gemäß einer Ausführungsform der vorliegenden Erfindung.

DETAILLIERTE BESCHREIBUNG DER BEVORZUGTEN AUSFÜHRUNGSFORM

[0041] Eine bevorzugte Ausführungsform der vorliegenden Erfindung wird nachfolgend unter Bezug auf die begleitenden Zeichnungen beschrieben. In der folgenden Beschreibung werden wohl bekannte Funktionen oder Konstruktionen nicht im Detail beschrieben, das sie die Erfindung durch unnötige Details verdecken würden.

[0042] In der folgenden Beschreibung werden die Inhalte, die sich nicht direkt auf Wesentliches der vorliegenden Erfindung beziehen, weggelassen. Für ein besseres Verständnis der vorliegenden Erfindung wird jedoch Bezug genommen auf die Inhalte, die von der 3GPP (3rd Generation Partnership Projekt) angenommen oder vorgelegt wurden. Obwohl die vorliegende Erfindung in Bezug auf ein NB-TDD Kommunikationssystem beschrieben wird, kann die Erfindung auch auf andere Kommunikationssysteme angewandt werden, die die Übertragungsleistung mit nur einem Leistungssteuerverfahren mit geschlossener Schleife nicht glatt steuern können, wie auf ein NB-TDD Kommunikationssystem. Ausführungsformen der vorliegenden Erfindung werden in Bezug auf einen ersten Fall, bei dem eine lange Übertragungspause in Abwärtsrichtung auftritt, einen zweiten Fall, bei dem lange Übertragungspausen sowohl in Abwärtsrichtung als auch in Aufwärtsrichtung auftreten, und einen dritten Fall, bei dem eine Strahlformungstechnik für die Übertragung in Abwärtsrichtung verwendet wird, beschrieben.

I. Übertragungspause in Abwärtsrichtung ist länger als Übertragungspause in Aufwärtsrichtung

[0043] Wenn eine lange Übertragungspause in Abwärtsrichtung zwischen der UE und dem Knoten B existiert, oder wenn die Übertragungspause in Abwärtsrichtung beachtlich länger als die Übertragung in Aufwärtsrichtung ist, treten die folgenden Probleme auf. Hier bezieht sich der Ausdruck "Pause" auf eine Periode, bei der tatsächlich keine Daten übertragen werden. Da eine lange Übertragungspause in Abwärtsrichtung vom Knoten B zur UE vorhanden ist, wird ein TPC-Befehl für das Steuern der Übertragungsleistung in Aufwärtsrichtung einer UE, der über einen physikalischen Kanal in Abwärtsrichtung oder einen gemeinsamen Kanal in Abwärtsrichtung empfangen werden soll, während der Übertragungspause in Abwärtsrichtung nicht übertragen. Somit ist es für die UE nicht möglich, eine Übertragungsleistung in Aufwärtsrichtung unter Verwendung des TPC-Befehls zu bestimmen. Da ferner kein zugewiesener physikali-

scher Kanal (DPCH) oder ein gemeinsamer Kanal vom Knoten B übertragen wird, kann die UE keinen TPC-Befehl für das Steuern der Übertragungsleistung des zugewiesenen Kanals in Abwärtsrichtung, der nach der Übertragungspause in Abwärtsrichtung übertragen wird, bestimmen. Um somit die Probleme zu lösen, die auftreten, wenn eine Übertragungspause in Abwärtsrichtung existiert, besteht eine Notwendigkeit eines Leistungssteuerverfahrens, in welchem die UE ihre Übertragungsleistung in Aufwärtsrichtung selbst während der Übertragungspause in Abwärtsrichtung bestimmt, und in dem sie ihre anfängliche Übertragungsleistung des Knotens B in Abwärtsrichtung nach der Übertragungspause in Abwärtsrichtung steuert. Dieses Leistungssteuerverfahren wird in Bezug auf erste und zweite Ausführungsformen beschrieben.

Erste Ausführungsform

[0044] Da kein zugewiesener Kanal in Abwärtsrichtung oder ein gemeinsamer Kanal in Abwärtsrichtung, der vom Knoten B übertragen wird, existiert, mißt die UE einen Ausbreitungsverlust zwischen dem Knoten B und der UE durch das Empfangen eines primären gemeinsamen physikalischen Steuerkanals (P-CCPCH), der vom Knoten B in einem ersten Zeitschlitz (TSO **101** der **Fig. 1**) jedes Unterrahmens oder Funkrahmens übertragen wird.

[0045] Die UE bestimmt die Übertragungsleistung in Aufwärtsrichtung durch das Durchführen einer Übertragungsleistungssteuerung mit offener Schleife auf der Basis des gemessenen Ausbreitungsverlusts, bestimmt einen TPC-Befehl für das Steuern einer Übertragungsleistung in Abwärtsrichtung unter Verwendung des Werts des Ausbreitungsverlusts, und überträgt den bestimmten TPC-Befehl an den Knoten B. Der Knoten B verwendet dann den TPC-Befehl, den er von der UE empfangen hat, beim Einstellen der anfänglichen Übertragungsleistung des Kanals in Abwärtsrichtung, der nach der Übertragungspause in Abwärtsrichtung übertragen werden soll. Ein Verfahren für das Durchführen der Leistungssteuerung mit offener Schleife durch das Messen eines Ausbreitungsverlusts des P-CCPCH wird dargestellt durch:

$$P_{up} = \alpha L_{P\text{-}CCPCH} + (1-\alpha)L_a + I_{BTS} + SIR_{target} + C \quad (1)$$

[0046] In der Gleichung (1) stellt P_{up} eine Übertragungsleistung eines Kanals in Aufwärtsrichtung, der von der UE zum Knoten B in einem spezifischen Zeitschlitz übertragen wird, dar; L_a stellt einen Mittelwert des P-CCPCH Ausbreitungsverlustes, der von der UE gemessen wird, dar; $L_{P\text{-}CCPCH}$ stellt einen aktuell gemessenen P-CCPCH Ausbreitungsverlust dar, und α ist ein Wichtungswert für den mittleren Ausbreitungsverlust und den aktuell gemessenen Ausbreitungsverlust. Hier wird, wenn der Wert α größer ist, die Übertragungsleistung der UE auf der Basis des aktuell gemessenen Ausbreitungsverlustes statt des mittleren Ausbreitungsverlustes bestimmt. Der Wert α steht in Beziehung zu einer Länge und einer Maßeinheit der Übertragungspause in Abwärtsrichtung. Wenn die Maßeinheit der Übertragungspause ein Zeitschlitz ist, wenn die Übertragungspause einen Zeitschlitz beträgt, so wird die Übertragungsleistung der UE unter ausschließlicher Verwendung des aktuell gemessenen Ausbreitungsverlustes von P-CCPCH bestimmt. Wenn die Übertragungspause länger wird, so wird die Übertragungsleistung der UE durch das Anwenden eines Wichtungswertes auf den mittleren Ausbreitungsverlust des P-CCPCH bestimmt. Wenn ferner die Maßeinheit der Übertragungspause ein Rahmen beträgt, das heißt, wenn die Übertragungspause 1 Rahmen lang ist, so kann die Übertragungsleistung der UE unter ausschließlicher Verwendung des aktuell gemessenen Ausbreitungsverlustes der P-CCPCH bestimmt werden. Zusätzlich kann die Übertragungsleistung der UE, wenn die Übertragungspause länger wird, unter Verwendung des mittleren Ausbreitungsverlustes der P-CCPCH bestimmt werden.

[0047] Die L_a und die $L_{P\text{-}CCPH}$ werden in Dezibel (dB) gemessen, und ein Übertragungsleistungspegel der P-CCPCH des Knotens B wird zu den UEs im Knoten B zusammen mit der Systeminformation (SI) eines Übertragungskanals, der über den P-CCPCH übertragen wurde, übertragen. I_{BTS} stellt ein Interferenzrauschen des Knotens B, das vom Knoten B in jedem Zeitschlitz gemessen wird, dar, und der Wert I_{BTS} wird auch zu den UEs durch den Übertragungskanal übertragen. SIR_{target}, ein vorbestimmtes Signal-zu-Interferenz-Zielverhältnis, wird gemäß einer Datenrate und dem Typ der Daten, die über den zugewiesenen Kanal übertragen werden, bestimmt. C, eine Konstante, ist ein Übertragungsleistungsversatz, der vom Knoten B an die UE geliefert wird. Im Übertragungsleistungssteuerverfahren mit offener Schleife korrigiert die UE einen Fehler des gemessenen Ausbreitungsverlusts des P-CCPCH durch die Addition eines spezifischen Übertragungsleistungsversatzes.

[0048] Hier kann das α der Gleichung (1) berechnet werden zu:

$$\alpha = 1 - [(D-1)/k] \quad (2)$$

[0049] In Gleichung (2) stellt D eine Übertragungspause dar, und ihr Ausdruck wird gemäß der Maßeinheit geändert. Das heißt, wenn D = 5 ist, wenn die Maßeinheit ein Zeitschlitz beträgt, so zeigt D eine Übertragungspause der fünffachen Schlitzlänge an; wenn die Maßeinheit ein Unterrahmen ist, so zeigt D eine Übertragungspause der fünffachen Unterrahmenlänge an; und wenn die Maßeinheit ein Rahmen ist, so zeigt D eine Übertragungspause der fünffachen Rahmenlänge an. In Gleichung (2) stellt k weiter die maximale Übertragungspause, für die ein α durch eine Formel berechnet werden kann, dar. Es kann ein beliebiger Wert für k verwendet werden, und der Wert k weist dieselbe Maßeinheit wie D auf. Das heißt, wenn D eine Zeitschlitzeinheit ist, so ist auch k eine Zeitschlitzeinheit; wenn D eine Unterrahmeneinheit ist, so ist auch k eine Unterrahmeneinheit; und wenn D eine Rahmeneinheit ist, so ist auch k eine Rahmeneinheit.

[0050] In der ersten Ausführungsform bestimmt der Knoten B die anfängliche Übertragungsleistung eines DPCH in Abwärtsrichtung oder eines DPCH in Aufwärtsrichtung, der nach dem Ende der Übertragungspause übertragen werden soll, unter Verwendung eines TPC-Befehls, der von der UE übertragen wird, in folgender Weise.

[0051] Der Knoten B kann die Übertragungsleistung des Transportkanals in Abwärtsrichtung durch das Hinzufügen oder Abziehen eines spezifischen Leistungspegels gemäß dem TPC-Befehl, der von der UE empfangen wurde, auf der Basis der Übertragungsleistung des Transportkanals in Abwärtsrichtung, der gerade vor der Übertragungspause in Abwärtsrichtung übertragen wurde, neu festsetzen. Das Verfahren für das neue Festsetzen der Übertragungsleistung des Transportkanals in Abwärtsrichtung wird dargestellt durch

$$P_{DL}[k] = P_{DL}[k-1] + \Delta TPC \times TPC \quad (3)$$

[0052] Vor einer Beschreibung der Gleichung (3) kann das NB-TDD Kommunikationssystem einen Übertragungsleistungssteuerschritt in jedem Zeitschlitz steuern, und 1, 2 und 3 dB sind für den Übertragungsleistungssteuerschritt verfügbar. In Gleichung (3) kann der ΔTPC-Wert in Abhängig-

keit vom Interferenzrauschen I_{BTS}, das durch einen Empfänger des Knotens B im entsprechenden Zeitschlitz gemessen wird, bestimmt werden. Das heißt, ΔTPC stellt den Übertragungsleistungssteuerschritt dar, der auf den k-ten Zeitschlitz angewandt werden soll, und TPC stellt einen TPC-Befehl in Abwärtsrichtung, der von der UE übertragen wird, dar. Der Knoten B kann den Kanal in Abwärtsrichtung zur UE, die den TPC-Befehl übertragen hat, unter Verwendung des TPC-Befehls, der von der UE übertragen wird, und der Gleichung (3) so wieder errichten, jedes Mal dann, wenn der TPC-Befehl von der UE empfangen wird, und wenn die Übertragungsdaten in Abwärtsrichtung erzeugt werden, so überträgt der Knoten B die Übertragungsdaten in Abwärtsrichtung unter Verwendung der neu errichteten Übertragungsleistung.

Zweite Ausführungsform

[0053] Die erste Ausführungsform wurde in Bezug auf das Übertragungsleistungssteuerverfahren in Aufwärtsrichtung/Abwärtsrichtung für den Fall, bei dem eine Übertragungspause in Abwärtsrichtung existiert, beschrieben. Ein anderes Übertragungsleistungssteuerverfahren für den Fall, bei dem eine Übertragungspause in Abwärtsrichtung existiert, wird in ein Verfahren für das Steuern der Übertragungsleistung in Aufwärtsrichtung aufgeteilt.

[0054] Zuerst wird das Übertragungsleistungssteuerverfahren in Aufwärtsrichtung gemäß der zweiten Ausführungsform der Erfindung dargestellt durch

$$P_{up} = P_{up}[0] + L_1 - L_0 + TPC_{offset} \quad (4)$$

[0055] In der Gleichung (4) stellt P_{up} die Übertragungsleistung in Aufwärtsrichtung der UE dar, die durch die UE als Übertragungsleistung in Aufwärtsrichtung gerade vor dem Start der Übertragungspause in Abwärtsrichtung verwendet wird; L_1 stellt einen Ausbreitungsverlust vom Knoten B zur UE dar, der von der UE in einem Zeitschlitz direkt vor dem Start der Übertragung in Aufwärtsrichtung der UE gemessen wird; und L_0 stellt einen Ausbreitungsverlust vom Knoten B zur UE dar, der durch die UE direkt vor der Start der Übertragungspause in Abwärtsrichtung des Knotens B gemessen wird. Weiter kann der Wert TPC_{offset} unter Berücksichtigung des TPC-Befehls, der durch die UE vor dem Start der Übertragungspause in Abwärtsrichtung und einer Änderung in der Kanalumgebung zwischen der UE und dem Knoten B empfangen wurde, bestimmt werden, und als Ergebnis wird TPCoffset durch eine Konstante dargestellt. Hier bezieht sich der Ausdruck "Kanalumgebung" auf eine Änderung im Ausbreitungsverlust vom Knoten B zur UE, gemessen durch die UE. Der Grund der Kompensation des Ausbreitungsverlusts zusätzlich zu L_1 und L_0 besteht darin, daß eine bloße Kompensation einer Differenz $L_1 - L_0$ ein Fehlen von Übertragungsleistung der UE verursachen kann, wenn der Ausbreitungsverlust eine abrupte Änderung erfährt.

[0056] Als zweites wird das Übertragungsleistungssteuerverfahren in Aufwärtsrichtung gemäß der zweiten Ausführungsform der vorliegenden Erfindung dargestellt durch:

$$P_{up} = P_{up}[0] + L_1 - L_0 + TPC_{offset}\, I_{BTS1} - I_{BTS0} \quad (5)$$

[0057] Ein Unterschied zwischen der Gleichung (4) und der Gleichung (5) besteht darin, daß die Interferenz der Empfängers des Knotens B, die durch den Empfänger des Knotens B gemessen wird, für die Übertragung in Aufwärtsrichtung der UE verwendet wird, nach der Übertragungspause in Abwärtsrichtung, wenn die Übertragungsleistung der UE bestimmt wird. In Gleichung (5) ist I_{BTS1} die Signalinterferenz des Empfängers des Knotens B, die vom Knoten B direkt vor dem Übertragungspunkt in Aufwärtsrichtung gemessen wird, und die zur UE durch den Übertragungskanal, der über den P-CCPCH übertragen wird, übertragen wird, und I_{BTS0} ist die Signalinterferenz des Empfängers des Knotens B in einem Zeitschlitz direkt vor dem Start der Übertragungspause in Aufwärtsrichtung.

[0058] Die Übertragungsleistungssteuerverfahren gemäß den ersten und zweiten Ausführungsformen der vorliegenden Erfindung wurden unter Bezug auf den Fall beschrieben, bei dem die Übertragungspause in Abwärtsrichtung existiert, oder bei dem die Übertragungspause in Abwärtsrichtung länger als die Übertragungspause in Aufwärtsrichtung ist. Als nächstes wird die Erfindung in Bezug auf den Fall beschrieben, bei dem die Übertragungspause in Aufwärtsrichtung und die Übertragungspause in Abwärtsrichtung beide lang sind.

II. Die Übertragungspause in Abwärtsrichtung und die Übertragungspause in Aufwärtsrichtung sind beide lang

[0059] Wenn sowohl die Übertragungspause in Abwärtsrichtung als auch die Übertragungspause in Aufwärtsrichtung lang sind, so wird der TPC-Befehl in der Übertragungspause in Aufwärtsrichtung und der Übertragungspause in Abwärtsrichtung zwischen dem Knoten B und der UE nicht übertragen, was es schwierig macht, die Leistungssteuerung mit geschlossener Schleife durchzuführen. Insbesondere weist, wenn sowohl die Übertragungspause in Aufwärtsrichtung als auch die Übertragungspause in Abwärtsrichtung beide lang sind, der Knoten B eine hohe Fehlerwahrscheinlichkeit auf, wenn er die anfängliche Übertragungsleistung in Abwärtsrichtung nach dem Ende der Übertragungspause in Abwärtsrichtung bestimmt, und wenn er die anfängliche Übertragungsleistung in Aufwärtsrichtung nach dem Ende der Übertragungspause in Aufwärtsrichtung bestimmt. Um dieses Problem zu lösen, liefert die vorliegende Erfindung die folgenden drei Verfahren zur Einstellung der anfänglichen Übertragungsleistung in Aufwärtsrichtung der UE nach dem Ende der Übertragungspause in Aufwärtsrichtung.

[0060] Das erste Verfahren besteht darin, das Verfahren zur Einstellung der Übertragungsleistung in Aufwärtsrichtung, das in der ersten Ausführungsform beschrieben wurde, zu verwenden. Das zweite Verfahren besteht darin, das Verfahren zur Einstellung der Übertragungsleistung in Aufwärtsrichtung, das in der zweiten Ausführungsform der vorliegenden Erfindung beschrieben wurde, zu verwenden. Das dritte Verfahren besteht darin, das erste Verfahren zusammen mit dem zweiten Verfahren zu verwenden. Das erste Verfahren, das heißt, die erste Ausführungsform, bestimmt die Übertragungsleistung in Aufwärtsrichtung der UE unter Verwendung des Leistungssteuerverfahrens mit offener Schleife, und das zweite Verfahren, das heißt die zweite Ausführungsform, bestimmt die Übertragungsleistung in Aufwärtsrichtung der UE unter Verwendung eines modifizierten Leistungssteuerverfahrens mit geschlossener Schleife. Das dritte Verfahren ergänzt das Leistungssteuerverfahren mit geschlossener Schleife und das Leistungssteuerverfahren mit offener Schleife, um eine Kompensation von Fehlern zu erreichen, die in den ersten und zweiten Verfahren auftreten können. Das dritte Verfahren kann folgendermaßen dargestellt werden:

$$P_{up} = f(n) \times P_{UL1} + (1 - f(n))\, P_{UL2} \quad (6)$$

[0061] In Gleichung (6) ist P_{UL1} gleich P_{up} der Gleichung (1), und P_{UL2} ist gleich P_{PL} der Gleichung (3). Weiter ist f(n)

eine Funktion einer Übertragungspause "n", und eine Einheit ist ein Funkrahmen oder ein Unterrahmen. Wenn die Übertragungspause länger ist, so hat f(n) die Eigenschaft, ein Gewicht der anfänglichen Übertragungsleistung in Aufwärtsrichtung, die im Leistungssteuerverfahren mit offener Schleife bestimmt wurde, zu erhöhen. Beispielsweise wird f(n) durch eine Funktion fn = 1/n dargestellt.

III. Strahlformungsübertragungstechnik die für eine Übertragung in Abwärtsrichtung verwendet wird

[0062] Im NB-TDD Kommunikationssystem wird, wenn eine Übertragungspause während einer Übertragung in Aufwärtsrichtung/Abwärtsrichtung unter einer Bedingung auftaucht, bei der eine spezielle Technik, wie eine Strahlformung verwendet wird, das gemeinsame Leistungsteuerverfahren mit geschlossener Schleife verwendet, da es schwierig ist, das gemeinsame Leistungssteuerverfahren mit offener Schleife zu verwenden. Der Grund für die Verwendung des Leistungssteuerverfahrens mit geschlossener Schleife statt des Leistungssteuerverfahrens mit offener Schleife besteht darin, daß der P-CCPCH, der für das Messen eines Ausbreitungsverlusts im Leistungssteuerverfahren mit offener Schleife verwendet wird, kein Subjekt der Strahlformung ist, während der DPCH oder der gemeinsame Kanal, der vom Knoten B zur UE übertragen wird, der Strahlformung unterliegt, so daß ein Ausbreitungsverlust, den der DPCH und der gemeinsame physikalische Kanal erfahren, sich von einem Ausbreitungsverlust, den der P-CCPCH erfährt, unterscheidet.

[0063] Die Strahlformungstechnik steuert eine Übertragungsrichtung eines Übertragungsstrahls und eine Richtung einer Empfangsantenne in einem Knoten B, so daß die UE das zugewiesene Kanalsignal, das vom Knoten B übertragen wird, effizienter empfangen kann, oder so daß der Knoten B das Signal, das durch die UE übertragen wird, effizienter empfangen kann. Im allgemeinen ist der Ausbreitungsverlust proportional zum Kehrwert der vierten Potenz der Distanz zwischen dem Knoten B und der UE. Wenn jedoch die Strahlformungstechnik angewandt wird, so ist der Ausbreitungsverlust proportional zum Kehrwert der zweiten Potenz der Distanz zwischen dem Knoten B und der UE.

[0064] Somit liefert die vorliegende Erfindung einen Übertragungsleistungssteueralgorithmus, der für das Einstellen einer Übertragungsleistung in Aufwärtsrichtung der UE in dem NB-TDD Kommunikationssystem, das die Strahlformungstechnik verwendet, verwendet wird. Die Übertragungsleistung der UE, die in dem Fall anwendbar ist, bei dem die Strahlformungstechnik verwendet wird, kann dargestellt werden zu:

$$P_{up} = P_{up}[0] + \beta(L_1 - L_0) + TPC_{offset} \quad (7)$$

$$P_{up} = P_{up}[0] + \beta(L_1 - L_0) + TPC_{offset} + I_{DTS1} - I_{DTS0} \quad (8)$$

[0065] Die Gleichungen (7) und (8) sind bis auf den Parameter β ähnlich den Gleichungen (4) beziehungsweise (5). Der Parameter β in Gleichung (7) ist derselbe Parameter wie der in Gleichung (8). Der Parameter b ist ein Wert für das Korrigieren eines Unterschieds zwischen einem Ausbreitungsverlust des DPCH oder des gemeinsamen physikalischen Kanals, die einer Strahlformung unterworfen werden, und eines Ausbreitungsverlusts des P-CCPCH, der keiner Strahlformung unterworfen ist. Der Grund dafür, daß der Parameter β benötigt wird, ist der, daß die UE ihre Übertragungsleistung durch das Empfangen eines TPC-Befehls, der über den zugewiesenen Kanal in Abwärtsrichtung oder den gemeinsamen physikalischen Kanal in Abwärtsrichtung vor der Übertragungspause in Abwärtsrichtung übertragen wird, steuert, aber sie den TPC-Befehl während der Übertragungspause in Abwärtsrichtung nicht empfangen kann, so daß die Übertragungsleistung unter Verwendung eines anderen Verfahrens eingestellt werden muß. Als ein Verfahren für das Einstellen der Übertragungsleistung war es für die UE möglich, einen Ausbreitungsverlust des P-CCPCH zu messen und die Gleichungen (4) und (5) zu verwenden. Wie oben angegeben wurde, wird jedoch, da sich eine Ausbreitungsverzögerung des DPCH oder des gemeinsamen Kanals von der des P-CCPCH durch die Strahlformung unterscheidet, die Differenz zwischen der Ausbreitungsverzögerung des gemessenen Kanals und der Ausbreitungsverzögerung des tatsächlich übertragenen Kanals unter Verwendung des Parameters β korrigiert. Der Parameter β wird dargestellt durch:

$$L_{DPCH} : L_{P\text{-}CCPCH} = (A/r^2) : (A/r^4) \quad (9)$$

wobei A die Übertragungsleistung des Knotens B darstellt.

[0066] Die Gleichung (9) berechnet ein Verhältnis des Ausbreitungsverlusts des P-CCPCH zu einem Ausbreitungsverlust des DPCH oder des gemeinsamen Kanals gemäß der Distanz zwischen der UE und dem Knoten B, und der Parameter β wird durch das berechnete Verhältnis bestimmt. In Gleichung (9) zeigt r die Distanz zwischen dem Knoten B und der UE an. Da der DPCH oder der gemeinsame Kanal einer Strahlformung unterworfen wird, steht sein Ausbreitungsverlust im inversen proportionalen Verhältnis zur zweiten Leistung der Distanz r zwischen dem Knoten B und der UE. Da jedoch der P-CCPCH keiner Strahlformung unterworfen wird, steht sein Ausbreitungsverlust im inversen Verhältnis zur vierten Potenz der Distanz r zwischen dem Knoten B und der UE.

[0067] Als nächstes wird eine Transceiverstruktur der UE und des Knotens B in Bezug auf die **Fig.** 4 und 5 beschrieben, wobei man annimmt, daß eine i-te UE Signale mit dem Knoten B austauscht.

[0068] **Fig.** 4 zeigt eine Struktur eines Transceivers einer UE gemäß einer Ausführungsform der vorliegenden Erfindung. Betrachtet man **Fig.** 4, so müssen, da das NB-TDD Kommunikationssystem dasselbe Frequenzband für die Übertragungen in Aufwärtsrichtung und Abwärtsrichtung zu verschiedenen Zeiten verwendet, ein Sender und ein Empfänger durch einen Schalter **420** geschaltet werden. Ein Kodierer **402** empfängt die Daten **401** des i-ten Benutzers, die zu einem Knoten B durch die UE zu übertragen sind, und Kanalkodes der empfangenen Benutzerdaten **401** in einem Faltungskode oder einem anderen Kanalzuteilungskode. Eine Verschachtelungsvorrichtung **403** verschachtelt die Daten, die vom Kodierer **402** ausgegeben werden, gemäß einer vorbestimmten Regel und liefert die verschachtelten Daten an einen Multiplexer **406**. Die Verschachtelung ordnet die Daten des i-ten Benutzers, die vom Kodierer **402** ausgegeben werden, gemäß der vorbestimmten Regel, um somit die mögliche schmalbandige Interferenz nach dem Entschachteln zu spreizen, um den Einfluß der schmalbandigen Interferenz zu minimieren.

[0069] Der Multiplexer **406** multiplext die Daten des i-ten Benutzers, die von der Verschachtelungsvorrichtung **403**, dem TPC **405**, dem TFCI **404** und der SS **460** ausgegeben werden, in einen Zeitschlitz (hier nachfolgend als "Datenteil des i-ten Benutzers" bezeichnet), der vom NB-TDD Kommunikationssystem verwendet wird, und liefert den Datenteil des i-ten Benutzers an eine Spreizvorrichtung **407**.

[0070] Der TPC **405**, ein Übertragungsleistungssteuerbefehl für das Steuern der Übertragungsleistung in Abwärtsrichtung vom Knoten B zur UE, wird durch einen Generator

490 für einen TPC-Befehl für die Abwärtsrichtung erzeugt. Wenn keine Übertragungspause in Abwärtsrichtung existiert, so vergleicht der Generator 490 des TPC-Befehls für die Abwärtsrichtung ein Signal-zu-Interferenzverhältnis (SIR), das durch einen zugewiesenen Kanal des i-ten Benutzers oder einen gemeinsamen physikalischen Kanal gemessen wird und von einer Entspreizvorrichtung 436 ausgegeben wird, mit einem Ziel-SIR (SIR_{target}). Wenn das gemessene SIR größer oder gleich dem Ziel-SIR ist, so erzeugt der TPC-Befehlsgenerator 490 in Abwärtsrichtung einen Leistungsabsenkbefehl in Abwärtsrichtung, ansonsten erzeugt, wenn das gemessene SIR kleiner als das Ziel-SIR ist, der TPC-Befehlsgenerator 490 in Abwärtsrichtung einen Leistungserhöhungsbefehl in Abwärtsrichtung.

[0071] Nach dem Auftreten einer Übertragungspause in Abwärtsrichtung erzeugt der TPC-Befehlsgenerator 490 in Abwärtsrichtung jedoch einen TPC-Befehl durch das Messen eines Ausbreitungsverlusts des P-CCPCH in einem gemeinsamen Kanal in Abwärtsrichtung (DSCH) 437, der von der Entspreizvorrichtung 436 ausgegeben wird. Der TPC-Befehl 405 wird zum Knoten B übertragen, so daß der Knoten B die Übertragungsleistung in Abwärtsrichtung, die nach dem Ende der Übertragungspause in Abwärtsrichtung verwendet werden soll, sogar während der Übertragungspause in Abwärtsrichtung neu einstellen kann. Weiterhin ist der TFCI 404 ein Kodewort, das verwendet wird, um Datenraten einer Vielzahl von Daten, die mit den Daten des i-ten Benutzers, die durch die UE übertragen werden, gemischt sind, zu bezeichnen. Die SS 460 stellt einen Befehl dar, um die Synchronisation eines Signals in Abwärtsrichtung zu steuern.

[0072] Die Spreizvorrichtung 407 empfängt den Datenteil des i-ten Benutzers, der durch den Multiplexer 406 geschaffen wird, spreizt den Datenteil des i-ten Benutzers, indem es ihn mit dem Kanalzuteilungskode multipliziert, und liefert ihr Ausgangssignal an einen Multiplizierer 408. Hier wird ein OVSF-Kode für den Kanalzuteilungskode, der im NB-TDD Kommunikationssystem verwendet wird, verwendet, und der OVSF-Kode ist ein orthogonaler Kode, wobei seine Länge gemäß einer Datenrate bestimmt wird. Der Kanalzuteilungskode dient dazu, den Kanal in Aufwärtsrichtung jeder UE zu unterscheiden, wenn eine Vielzahl von UEs gleichzeitig Daten im NB-TDD Kommunikationssystem übertragen, und er spreizt auch ein Übertragungsband der Benutzerdaten gemäß ihrer Länge.

[0073] Der Multiplizierer 408 multipliziert ein Signal, das von der Spreizvorrichtung 407 ausgegeben wird, mit einem Kanalverstärkungsparameter und liefert sein Ausgangssignal an einen Multiplizierer 409. Hier wird der Kanalverstärkungsparameter durch eine Übertragungsleistungssteuervorrichtung in Aufwärtsrichtung 480 geschaffen, um einen Übertragungsparameter des Kanals in Aufwärtsrichtung des i-ten Benutzers zu bestimmen. Wenn keine Übertragungspause in Abwärtsrichtung vorhanden ist, so wird der Kanalverstärkungsparameter in Abhängigkeit von Typ der Daten, die durch den Datenteil des i-ten Benutzers übertragen werden, und von einem TPC-Befehl, der vom Knoten B übertragen wird, geschaffen. Beim Auftreten einer Übertragungspause in Abwärtsrichtung wird der Kanalverstärkungsparameter jedoch durch die Gleichungen (1), (4) und (5) bestimmt. Wenn keine Übertragungspause in Abwärtsrichtung vorhanden ist, so erzeugt die Übertragungsleistungssteuerung 480 in Aufwärtsrichtung den Kanalverstärkungsparameter auf der Basis eines TPC-Befehls 439, der von einem Demultiplexer 438 ausgegeben wird. Nach dem Auftreten der Übertragungspause in Abwärtsrichtung erzeugt jedoch die Übertragungsleistungssteuervorrichtung 480 in Aufwärtsrichtung den Kanalverstärkungsparameter unter Verwendung eines Ausbreitungsverlusts des P-CCPCH im gemeinsamen Kanal (DSCH) 437 in Abwärtsrichtung, der von der Entspreizvorrichtung 436 ausgegeben wird.

[0074] Der Multiplexer 409 verwürfelt ein Signal, das vom Multiplizierer 408 ausgegeben wird, indem er es mit einem Verwürfelungskode $C_{scramble}$ multipliziert, und er liefert sein Ausgangssignal an einen Multiplexer 411. Hier wird der Verwürfelungskode $C_{scramble}$ für die Identifikation des Knotens B und der UE und eine Reduktion der Kreuzkorrelation der Mehrwegesignale verwendet. Im NB-TDD Kommunikationssystem wird der Verwürfelungskode nur für die Identifikation des Knotens B und die Reduktion in der Kreuzkorrelation verwendet. Im NB-TDD Kommunikationssystem verwendet jeder Knoten B seinen eigenen eindeutigen Verwürfelungskode, und der Verwürfelungskode wird sowohl für die Übertragung in Aufwärtsrichtung als auch die Übertragung in Abwärtsrichtung verwendet. Der Multiplexer 411 multiplext ein Signal, das vom Multiplizierer 409 ausgegeben wird, und eine Mitambel 410 in einen Kanal des iten Benutzers in Aufwärtsrichtung, wobei eine Basisübertragungseinheit dieses Kanals ein Zeitschlitz beträgt. Der Kanal des i-ten Benutzers in Aufwärtsrichtung besteht aus den Benutzerdaten 401, dem TPC 405, TFCI 404, der Mitambel 410 und einer GP (Schutzperiode). Die Mitambel 410 wird für eine Kanalschätzung und eine Mehrfachbenutzerdetektion, die durch das NB-TDD Kommunikationssystem unterstützt wird, verwendet, und die GP ist eine Periode, die geschaffen wurde, um ein Interferenzrauschen zwischen den übertragungssignalen in Aufwärtsrichtung und Abwärtsrichtung, die durch eine Überlappung eines Zeitschlitzes in Aufwärtsrichtung und eines Zeitschlitzes in Abwärtsrichtung im NB-TDD Kommunikationssystem verursacht wird, zu verhindern. In der Schutzperiode werden tatsächlich keine Daten übertragen.

[0075] Ein Modulator 412 moduliert den Kanal des i-ten Benutzers in Aufwärtsrichtung, der vom Multiplexer 411 ausgegeben wird, in einem vorbestimmten Modulationmodus, und liefert sein Ausgangssignal an den Schalter 420. Hier umfaßt die Modulationstechnik QPSK (Quadratur-Phasen-Verschiebungs-Verschlüsselung), 8PSK (8-fach Phasenumtastung) und QAM (Quadraturamplitudenmodulation). Der Schalter 420 wird in die eingeschaltete Stellung geschaltet, um den Kanal des i-ten Benutzers in Aufwärtsrichtung, der vom Modulator 412 ausgegeben wird, zum Knoten B in einem Zeitschlitz zu übertragen, in dem der Kanal des i-ten Benutzers in Aufwärtsrichtung zu übertragen ist. Der Schalter 420 wird durch eine Steuervorrichtung 421 gesteuert, die einen Übertragungspunkt des Kanals in Aufwärtsrichtung steuert. Auf der Basis der Unterrahmenstruktur des NB-TDD Kommunikationssystems steuert die Steuervorrichtung 421 einen Übertragungspunkt eines Pilotzeitschlitzes in Aufwärtsrichtung (UpPTS), einen Übertragungspunkt eines Pilotzeitschlitzes in Abwärtsrichtung (DwPTS), und einen Ankunftspunkt eines Kanals in Abwärtsrichtung vom Knoten B zur UE.

[0076] Hier wird der UpPTS durch einen UpPTS-Generator 430 erzeugt. Der PuPTS wird übertragen, wenn die UE einen Kanal vom Knoten B zugewiesen bracht, oder in einem Übergangszustand, und der UpPTS wird durch den Knoten B beim Steuern eines Kriteriums für das Bestimmen der Übertragungsleistung in Aufwärtsrichtung der UE oder zur Steuerung der Übertragungssynchronisation in Aufwärtsrichtung verwendet. Die UE empfängt den DwPTS während ihrer anfänglichen Suche nach dem Knoten B, und der DwPTS bezeichnet eine Position des P-CCPCHs, wo der Übertragungskanal mit der Systeminformation übertragen wird, und eine Position in einer Mehrrahmenstruktur, wo die

UE aktuell einen Rahmen in Abwärtsrichtung empfängt. Im NB-TDD Kommunikationssystem lenkt für einen Datenaustausch der Knoten B eine vorbestimmte Anzahl von 10 ms Funkrahmen, und typischerweise bilden 64 oder 72 Funkrahmen eine Mehrrahmenstruktur. Der Kanal in Aufwärtsrichtung, der vom Schalter **420** ausgegeben wird, wird auf ein Trägerfrequenzband in der Frequenz durch einen RF-Prozessor **422** verschoben und dann zum Knoten B durch eine Antenne **423** übertragen.

[0077] Bis hierher wurde ein Verfahren für das Übertragen eines Kanals in Aufwärtsrichtung von der UE zum Knoten B beschrieben. Als nächstes wird ein Verfahren für das Empfangen eines Abwärtsverbindungskanals vom Knoten B beschrieben.

[0078] Ein Signal eines Kanals in Abwärtsrichtung, das durch die Antenne **423** empfangen wird, wird durch den RF-Prozessor **422** von der Frequenz des Trägerbands zur Frequenz des Basisbands in der Frequenz verschoben und dann dem Schalter **420** angeboten. Der Schalter **420** schaltet das Signal, das vom RF-Prozessor **422** ausgegeben wird, an und liefert sein Ausgangssignal unter der Steuerung der Steuervorrichtung **421** an den Demodulator **432** an einem Punkt, an dem ein Signal eines Kanals in Aufwärtsrichtung empfangen werden soll. Das Signal, das an der i-ten UE vom Knoten B empfangen wird, kann den DwPTS einschließen, und der Schalter **420** wird in Richtung einer DwPTS-Analysevorrichtung **431** an einem Ankunftspunkt des DwPTS geschaltet, um eine empfangene DwPTS an die DwPTS-Analysevorrichtung **431** zu liefern. Die DwPTS-Analysevorrichtung **431** analysiert den empfangenen DwPTS, so daß die UE eine Position eines Übertragungskanals und eine Position des aktuell empfangenen Rahmens in Abwärtsrichtung in der Mehrrahmenstruktur erkennen kann. Der Demodulator **432** demoduliert das empfangene Signal des Kanals in Abwärtsrichtung in der Modulationsart, die vom Knoten B verwendet wird, und liefert das demodulierte Signal an einen Demultiplexer **433**. Der Demultiplexer **433** demultiplext das Signal des Kanals in Abwärtsrichtung in eine Mitambel **434** und einen Benutzerdatenteil in Abwärtsrichtung. Die Mitambel **434**, die vom Demultiplexer **433** ausgegeben wird, dient dazu, einen Empfangsleistungspegel des Signals des Kanals in Abwärtsrichtung, das vom Knoten B übertragen wurde, zu messen, und es ermöglicht der UE, den Typ der Kanals in Abwärtsrichtung, der vom Knoten B übertragen wird, zu erkennen. Somit ist es durch eine einfache Analyse der Mitambel **434** möglich, zu erkennen, ob Daten zur UE übertragen werden.

[0079] Ein Multiplizierer **435** entwürfelt den Benutzerdatenteil in Abwärtsrichtung, der vom Demultiplexer **433** ausgegeben wird, indem er ihn mit demselben Verwürfelungskode $C_{scramble}$, wie er vom Knoten B verwendet wird, multipliziert, und er liefert sein Ausgangssignal an die Entspreizvorrichtung **436**. Die Entspreizvorrichtung **436** entspreizt die gespreizten Benutzerdaten und den gemeinsamen Kanal in Abwärtsrichtung durch das Multiplizieren eines Signals, das vom Multiplizierer **435** ausgegeben wird, mit dem Kanalzuteilungskode, einem OVSF-Kode, der im Knoten B verwendet wird, um somit die Benutzerdaten in Abwärtsrichtung und den gemeinsamen Kanal **437** in Abwärtsrichtung für die Übertragung der Systeminformation des Knotens B oder der UE-Steuerinformation zu extrahieren. Wenn eine Übertragungspause in Abwärtsrichtung im gemeinsamen Kanal **437** in Abwärtsrichtung existiert, so wird der P-CCPCH verwendet, um die Übertragungsleistung in Aufwärtsrichtung festzulegen.

[0080] Die i-ten Benutzerdaten, die von der Entspreizvorrichtung **436** ausgegeben werden, werden durch einen Demultiplexer **438** in TPC **439**, TFCI **440**, SS **470** und reine Benutzerdaten demultiplext. Der TPC_Befehl **439** wird verwendet, um die Übertragungsleistung des Kanals in Aufwärtsrichtung, die durch die UE des i-ten Benutzers übertragen werden soll, zu steuern, der TFCI **440** wird verwendet, um den Typ der Daten, die vom Knoten B zum i-ten Benutzer übertragen werden, zu analysieren, und die SS **470** wird vom Knoten B als ein Befehl für das Anfordern der Synchronisationssteuerung des Kanals in Aufwärtsrichtung, der durch die UE übertragen wird, verwendet. Die i-ten Benutzerdaten, die vom Demultiplexer **438** ausgegeben werden, werden durch eine Entschachtelungsvorrichtung **441** entschachtelt und dann durch einen Dekodierer **442** als die Daten **443** des i-ten Benutzers dekodiert.

[0081] **Fig. 5** zeigt eine Struktur eines Transceivers des Knotens B gemäß einer Ausführungsform der vorliegenden Erfindung.

[0082] Zuerst wird ein Verfahren für das Übertragen von Kanälen in Abwärtsrichtung vom Knoten B zu den UEs unter Bezug auf **Fig. 5** beschrieben. Ein Kodierer **502** führt eine Kanalkodierung der Daten **501** des i-ten Benutzers, die zum i-ten Benutzer übertragen werden sollen, durch und liefert sein Ausgangssignal an eine Verschachtelungsvorrichtung **503**. Die Verschachtelungsvorrichtung **503** verschachtelt ein Signal, das vom Kodierer **502** ausgegeben wird, gemäß einer vorbestimmten Regel und liefert ihr Ausgangssignal an einen Multiplexer **506**. Der Multiplexer **506** multiplext die Daten des i-ten Benutzers, die von der Verschachtelungsvorrichtung **503** ausgegeben werden, und einen TPC-Befehl **505** für das Steuern, der Übertragungsleistung in Aufwärtsrichtung des i-ten Benutzers, eine TFCI **504**, die ein Transportformat anzeigt, das für die Daten des i-ten Benutzers verwendet wird, und eine SS **560** für das Anfordern einer Synchronisationssteuerung auf dem Transportkanal in Aufwärtsrichtung vom UE, um den Datenteil des i-ten Benutzers zu erzeugen, und sie liefert dann den erzeugten Datenteil des i-ten Benutzers an eine Spreizvorrichtung **507**. Hier wird der TPC **505** durch einen TPC-Befehlsgenerator **590** für die Aufwärtsrichtung durch das Messen des SIR eines Transportkanals in Aufwärtsrichtung des i-ten Benutzers, der von einer Entspreizvorrichtung **535** ausgegeben wird, geschaffen.

[0083] Die Spreizvorrichtung **507** führt eine Kanalspreizung des Datenteils des i-ten Benutzers mit dem OVSF-Kode, der für den Kanal in Abwärtsrichtung des i-ten Benutzers verwendet wird, durch, und liefert ihr Ausgangssignal an einen Multiplizierer **508**. Der Multiplizierer **508** multipliziert ein Signal, das von der Spreizvorrichtung **507** ausgegeben wird, mit einer Kanalverstärkung für die Übertragungsleistung des Kanals in Abwärtsrichtung, der zum i-ten Benutzer übertragen werden soll, und liefert sein Ausgangssignal an einen Summierer **511**. Hier wird die Kanalverstärkung durch einen Übertragungsleistungssteuervorrichtung **580** in Abwärtsrichtung auf der Basis eines TPC-Befehls **537** der Abwärtsrichtung, der vom Demultiplexer **536** ausgegeben wird, geschaffen. Nach dem Auftreten einer Übertragungspause in der Abwärtsrichtung stellt die Übertragungsleistungssteuerung **580** in Abwärtsrichtung die Übertragungsleistung in Abwärtsrichtung, die am Endpunkt der Übertragungspause in Abwärtsrichtung verwendet werden soll, unter Verwendung von Gleichung (3) ein.

[0084] Der Summierer **511** summiert einen gemeinsamen Kanal **510** in Abwärtsrichtung, bei dem es sich nicht um die Kanäle **509** in Abwärtsrichtung des Benutzers handelt, und den Kanal des i-ten Benutzers vom Multiplexer **508**, wobei die Kanäle mit verschiedenen OVSF-Kodes einer Kanalspreizung unterzogen werden, so daß die Kanäle keine Interferenz mit den anderen Kanälen der Benutzers, die zusammen mit ihnen aufsummiert wurden, bilden können. Ein

Multiplizierer **512** verwürfelt die Kanalsignale in Abwärtsrichtung, die vom Summierer **511** ausgegeben werden, mit dem Verwürfelungskode, der vom Knoten B verwendet wird, und er liefert sein Ausgangssignal an einen Multiplexer **514**. Der Multiplexer **514** multiplext die Kanalsignale in Abwärtsrichtung und eine eingegebene Mitambel **513** in einen Zeitschlitz eines Kanals in Abwärtsrichtung. Die Mitambel **513** kann durch die UE beim Messen eines Übertragungsleistungspegels des Knotens B verwendet werden, und sie kann auch bei der Bestimmung der Kanäle, die über den Zeitschlitz des Kanals in Übertragungsrichtung übertragen werden, die durch den Multiplexer **514** gemultiplext wurden, verwendet werden.

[0085] Ein Modulator **515** moduliert die Signale des Kanals in Abwärtsrichtung, die vom Multiplexer **514** ausgegeben werden, in einer Modulationsart, wie BPSK (Binäre Phasenlagenverschlüsselung), QPSK, 8PSK oder QUAM. Die modulierten Signale des Kanals in Abwärtsrichtung, die vom Modulator **515** ausgegeben werden, werden einem Schalter **520** geliefert, der zum Modulator **515** an einem Übertragungspunkt des Kanalschlitzes in Abwärtsrichtung unter der Steuerung einer Steuervorrichtung **521** weiterleitet. Das Signal, das vom Schalter **520** ausgegeben wird, wird an einen RF-Prozessor **522** geliefert. Ferner wird der Schalter **520** zu einem DwPTS-Generator **516** unter der Steuerung der Steuervorrichtung **521** geschaltet, um die DwPTS an einem Übertragungspunkt der DwPTS zu übertragen. Die DwPTS wird durch die UE verwendet, um eine Position eines Übertragungskanals mit der Information des Knotens B, einen Pegel eines Signals des Knotens B und eine Position eines aktuell empfangen Rahmens in der Mehrrahmenstruktur während einer anfänglichen Suche nach dem Knoten B zu schätzen. Der RF-Prozessor **522** führt eine Frequenzverschiebung des Zeitschlitzes des Kanals in Abwärtsrichtung auf ein Trägerfrequenzband durch, und er überträgt seine Ausgangssignale an die UEs im Knoten B durch eine Antenne **523**.

[0086] Als nächstes wird ein Verfahren für das Empfangen von Signalen in Aufwärtsrichtung von den UEs im Knoten B unter Bezug auf **Fig. 5** beschrieben. Der RF-Prozessor **522** führt eine Frequenzverschiebung von Signalen in Aufwärtsrichtung, die durch die Antenne **523** empfangen werden, in ein Basisband durch, und er liefert sein Ausgangssignal dann an den Schalter **520**. Der Schalter **520** schaltet unter der Steuerung der Steuervorrichtung **521** die Signale in Aufwärtsrichtung, die von den UEs empfangen werden, zu einem Demodulator **531** zu einer spezifizierten Zeit. Die Steuervorrichtung **521** steuert den Schalter **520** durch das Analysieren der Punkte, an denen die UEs im Knoten B die Signale des Kanals in Aufwärtsrichtung übertragen haben, und sie schaltet auch den Schalter **520** (oder verbindet ihn) mit einer UpPTS-Analysevorrichtung **530** an einem Ankunftspunkt der UpPTS, um so die UpPTSs, die von den jeweiligen UEs übertragen werden, zu analysieren. Der Demodulator **531** demoduliert das empfangene Signal in Aufwärtsrichtung und liefert sein Ausgangssignal an einen Demultiplexer **532**. Der Demultiplexer **532** demultiplext das empfangene Signal in Aufwärtsrichtung, das vom Demodulator **531** ausgegeben wird, in eine Mitambel **533** und einen Signaldatenteil in Aufwärtsrichtung. Die Mitambel **533** wird bei der Detektion der Benutzer, dem Schätzen der Kanalumgebung zwischen den UEs und dem Knoten B und dem Schätzen eines Pegels der Übertragungssignale von den UEs verwendet. Der Datenteil des Signals in Aufwärtsrichtung, der vom Demultiplexer **532** ausgegeben wird, wird durch einen Multiplizierer mit demselben Verwürfelungskode, wie er im UE-Transceiver der **Fig. 4** verwendet wurde, entwürfelt. Der entwürfelte Datenteil des Signals in Aufwärtsrichtung wird durch die Entspreizvorrichtung **535** in Datenteile des Signals in Aufwärtsrichtung der entsprechenden Benutzer entspreizt, und der Datenteil des Signals in Aufwärtsrichtung des i-ten Benutzers wird an einen Demultiplexer **536** geliefert. Der Demultiplexer **536** demultiplext den Datenteil des Signals in Aufwärtsrichtung des i-ten Benutzers in TPC **537**, TFCI **538**, SS **570** und die i-ten Benutzerdaten. Der TPC **537** wird der Übertragungsleistungssteuerung **580** in Abwärtsrichtung geliefert und verwendet, um die Übertragungssignalleistung der Abwärtsverbindung des i-ten Benutzers zu steuern. Der TFCI **538** wird bei einer Analyse eines Transportformats, das für den Datenteil des i-ten Benutzers verwendet wird, verwendet, und die SS **570** wird bei der Steuerung eines Übertragungspunkts des Kanals in Abwärtsrichtung zur UE verwendet. Die i-ten Benutzerdaten, die vom Demultiplexer **536** ausgegeben werden, werden durch eine Entschachtelungsvorrichtung **539** entschachtelt, und dann durch einen Dekodierer **540** in die Daten **541** des i-ten Benutzers dekodiert. Die anderen Kanäle **550** in Aufwärtsrichtung der anderen Benutzers, die von der Entspreizvorrichtung **535** ausgeben werden, werden auch am Knoten B im selben Verfahren, wie es mit den Daten des i-ten Benutzers durchgeführt wurde, empfangen.

[0087] **Fig.** 6 zeigt ein Betriebsverfahren der UE gemäß einer Ausführungsform der vorliegenden Erfindung. Betrachtet man **Fig.** 6, so führt in Schritt **601** die UE eine normale Übertragungsleistungssteuerung in Aufwärtsrichtung/Abwärtsrichtung durch, wobei sie typischerweise das Leistungssteuerverfahren mit geschlossener Schleife im NB-TDD Kommunikationssystem verwendet. Wenn die UE eine Übertragungspause in Abwärtsrichtung in Schritt **602** während der Leistungssteuerung mit geschlossener Schleife erkennt, so geht die UE zur Schritt **603** weiter. Hier kann die UE die Übertragungspause in Abwärtsrichtung durch das Analysieren einer Signalisierungsnachricht einer oberen Lage, die vom Knoten B übertragen wird, detektieren, oder sie kann die Übertragungspause in Abwärtsrichtung nach der mißlungenen Detektion einer Mitambel, die der UE in einem Mitambelteil des Kanals in Abwärtsrichtung, der vom Knoten B übertragen wurde, zugeordnet wurde, erkennen.

[0088] Nach dem Erkennen der Übertragungspause in Abwärtsrichtung mißt die UE einen Ausbreitungsverlust des P-CCPCH, der vom Knoten B übertragen wird, im Schritt **603** und geht dann zum Schritt **604** weiter. Natürlich kann die UE auch den Ausbreitungsverlust des P-CCPCH in Schritt **601** messen. Nach dem Messen des Ausbreitungsverlusts des P-CCPCH bestimmt die UE in Schritt **604**, ob eine Übertragungspause in Aufwärtsrichtung aufgetreten ist, da die UE in zwei unterschiedlichen Betriebsarten arbeitet, in Abhängigkeit davon, ob Übertragungsdaten in Aufwärtsrichtung existieren. Nach dem Auftreten der Übertragungspause in Aufwärtsrichtung in Schritt **604** stellt die UE die Übertragungsleistung in Aufwärtsrichtung unter Verwendung des Ausbreitungsverlusts des P-CCPCH, der Interferenzrauschens I_{BTS} des Knotens B und der Übertragungsleistung des Übertragungszeitschlitzes in Aufwärtsrichtung direkt vor dem Start der Übertragungspause in Abwärtsrichtung in **611** neu ein und geht dann zu Schritt **612** weiter. Hier wird das Verfahren der Neueinstellung der Übertragungsleistung in Aufwärtsrichtung in derselben Art, wie es in den Ausführungsformen der vorliegenden Erfindung beschrieben wurde, durchgeführt. In Schritt **612** bestimmt die UE, ob Übertragungsdaten in Aufwärtsrichtung existieren. Wenn keine Übertragungsdaten in Aufwärtsrichtung existieren, so kehrt die UE zum Schritt **611** zurück. Ansonsten geht die UE zum Schritt **606** weiter.

[0089] Wenn in Schritt **604** Übertragungsdaten in Aufwärtsrichtung existieren, so geht die UE zum Schritt **605** weiter, wo sie die Übertragungsleistung in Aufwärtsrichtung bestimmt und einen TPC-Befehl in Abwärtsrichtung bildet. Hier wird der TPC-Befehl in Abwärtsrichtung von der UE zum Knoten B übertragen und dann vom Knoten B bei der Bestimmung der Übertragungsleistung des Kanals in Abwärtsrichtung, der direkt nach der Übertragungspause in Abwärtsrichtung verwendet werden soll, das heißt, beim Einstellen der anfänglichen Übertragungsleistung des Kanals in Abwärtsrichtung, verwendet. Im Schritt **606** überträgt die UE den TPC-Befehl in Abwärtsrichtung, der im Schritt **605** oder **611** bestimmt wurde, und die Benutzerdaten zum Knoten B mit der bestimmten Übertragungsleistung in Aufwärtsrichtung. Im Schritt **607** bestimmt die UE, ob ein zugewiesener Kanal in Abwärtsrichtung oder ein gemeinsamer Kanal in Abwärtsrichtung vom Knoten B empfangen wird. Als Ergebnis der Bestimmung kehrt die UE, wenn kein zugewiesener Kanal in Abwärtsrichtung oder kein gemeinsamer Kanal in Abwärtsrichtung vom Knoten B empfangen wird, zum Schritt **603** zurück. Wenn jedoch der zugewiesene Kanal in Abwärtsrichtung oder der gemeinsame Kanal vom Knoten B empfangen wird, so steuert die UE in Schritt **608** die Übertragungsleistung der Abwärtsverbindung in einer normalen Leistungssteuerbetriebsart, das heißt einer Leistungssteuerbetriebsart mit geschlossener Schleife.

[0090] **Fig.** 7 zeigt ein Betriebsverfahren des Knotens B gemäß einer Ausführungsform der vorliegenden Erfindung. Betrachtet man **Fig.** 7, so steuert der Knoten B in Schritt **701** die Übertragungsleistung in Aufwärtsrichtung/Abwärtsrichtung in einer normalen Leistungssteuerbetriebsart, das heißt in der Leistungssteuerbetriebsart mit geschlossener Schleife, einer typischen Leistungssteuerbetriebsart im NB-TDD Kommunikationssystem. Da der Knoten B in zwei unterschiedlichen Betriebsarten in Abhängigkeit davon, ob einer Übertragungspause in Abwärtsrichtung während der normalen Übertragungsleistungssteueroperation in Aufwärtsrichtung/Abwärtsrichtung auftritt, arbeitet, bestimmt der Knoten B in Schritt **702**, ob einer Übertragungspause in Abwärtsrichtung auftritt. Bei Auftreten der Übertragungspause in Abwärtsrichtung stellt der Knoten B die Übertragungsleistung in Abwärtsrichtung unter Verwendung eines TPC-Befehl, der von der UE empfangen wird, in Schritt **703** neu ein, und geht dann weiter zu Schritt **704**. Wenn jedoch keine Übertragungspause in Abwärtsrichtung im Schritt **702** auftaucht, so kehrt der Knoten B zum Schritt **701** zurück. Der Knoten B bestimmt im Schritt **704**, ob es Übertragungsdaten in Abwärtsrichtung gibt. Als Ergebnis der Bestimmung kehrt der Knoten B, wenn keine Übertragungsdaten in Abwärtsrichtung vorhanden sind, zum Schritt **703** zurück, und ansonsten geht der Knoten B, wenn Übertragungsdaten in Abwärtsrichtung vorhanden sind, zum Schritt **705** weiter. Im Schritt **705** erzeugt der Knoten einen TPC-Befehl in Aufwärtsrichtung durch das Messen eines Leistungspegels eines Signals, das von der UE empfangen wird, und überträgt den TPC-Befehl in Aufwärtsrichtung und die Benutzerdaten zur UE mit der Übertragungsleistung, die in Schritt **703** bestimmt wurde. Danach steuert in Schritt **706** der Knoten B die Übertragungsleistung in Aufwärtsrichtung/Abwärtsrichtung wieder in der normalen Übertragungsleistungssteuerbetriebsart.

[0091] Wie oben beschrieben wurde, verwendet das NB-TDD Kommunikationssystem gemäß der vorliegenden Erfindung das Leistungssteuerverfahren mit geschlossener Schleife zusammen mit dem Leistungssteuerverfahren mit offener Schleife für eine Übertragungsleistungssteuerung in Aufwärtsrichtung nach dem Auftreten einer Übertragungspause in Aufwärtsrichtung/Abwärtsrichtung, um somit eine effiziente Leistungssteuerung durchzuführen. Zusätzlich kann, wenn eine spezielle Technik des Empfangs/des Sendens, wie eine Strahlungsformung angewandt wird, das NT-TDD Kommunikationssystem wirksam die Übertragungsleistung in Aufwärtsrichtung/Abwärtsrichtung unter Berücksichtigung der Unterschiede in den Eigenschaften zwischen den Kanälen, die einer Strahlformung unterworfen wurden, und den Kanälen, die keiner Strahlformung unterworfen wurden, steuern, um es für den Knoten B und die UE möglich zu machen, ihre passende anfängliche Übertragungsleistung am Ende der Übertragungspause einzustellen.

[0092] Während die Erfindung unter Bezug auf gewisse bevorzugte Ausführungsformen gezeigt und beschrieben wurde, werden Fachleute verstehen, daß verschiedene Änderungen in der Form und den Details vorgenommen werden können, ohne von der Idee und dem Umfang der Erfindung, wie sie durch die angefügten Ansprüche definiert ist, abzuweichen.

Patentansprüche

1. Übertragungsleistungssteuerverfahren in einer UE (Benutzerausrüstung) für ein TDD (Zeitduplex) CDMA (Vielfachzugriff durch Kodetrennung) Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder der Rahmen ein Feld, das den Leistungspegel der Information, die vom Knoten B übertragen wird, angibt, und einen Zeitschlitz für das Zuweisen eines TPC-(Übertragungsleistungssteuerungs)-Befehls und der Übertragungsdaten vom Knoten B an die UE umfaßt, wobei die UE die Daten, die vom Knoten B übertragen werden, empfängt, wobei sie einem Zeitschlitzfeld im folgenden Rahmen nach einer Übertragungspausenzeitdauer, bei der keine Übertragungsdaten im Zeitschlitzfeld im speziellen Rahmen existieren, unter dem Strom von Rahmen, die vom Knoten B zur UE übertragen werden, zugewiesen sind, wobei das Verfahren die folgenden Schritte umfaßt:

Messen eines Ausbreitungsverlusts zwischen dem Knoten B und der UE durch das Empfangen der Leistungspegelinformation in einem spezifischen Zeitschlitz in der Übertragungspausenzeitdauer;

Messen eines Interferenzrauschens des Knotens B durch das Empfangen einer speziellen Kanalsignals, das durch den Knoten B übertragen wird;

Bestimmen einer Übertragungsleistung in Aufwärtsrichtung durch das Summieren (i) von Werten, die durch das Anlegen eines Gewichts, basierend auf der Länge der Übertragungspausenzeitdauer, auf den aktuell gemessenen Ausbreitungsverlust und einen mittleren Ausbreitungsverlust zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer bestimmt werden, (ii) eines vorbestimmten Ziel-Signal-zu-Interferenz-Verhältnisses (SIR), (iii) des gemessenen Interferenzrauschens des Knotens B und (iv) eines Versatzes für das Kompensieren des Ausbreitungsverlustfehlers; und

Übertragen eines TPC-Befehls, der der bestimmten Übertragungsleistung in Aufwärtsrichtung entspricht, zum Knoten B.

2. Übertragungsleistungssteuerverfahren nach Anspruch 1, wobei es weiter den Schritt der Bestimmung einer Übertragungsleistung in Abwärtsrichtung durch den Knoten B nach dem Empfang des TPC-Befehls umfaßt, wobei (i) eine Übertragungsleistung in Abwärtsrichtung, die in einem Zeitschlitz direkt vor der Übertragungspausenzeitdauer im folgenden Rahmen

übertragen wird, (ii) der empfangene TPC-Befehl und (iii) ein Leistungssteuerschritt, der auf einen entsprechenden Zeitschlitz im folgenden Rahmen angewandt werden soll, berücksichtigt werden.

3. Übertragungsleistungssteuerverfahren nach Anspruch 1, wobei der spezifische Kanal ein Funkübertragungskanal ist.

4. Übertragungsleistungssteuerverfahren in einer UE für ein TDD CDMA Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder der Rahmen ein Feld, das die Leistungspegelinformation, die vom Knoten B übertragen wird, anzeigt, und ein Zeitschlitzfeld für das Zuweisen eines TPC-Befehls und Übertragungsdaten vom Knoten B zur UE einschließt, wobei die UE Daten empfängt, die vom Knoten B übertragen wurden, diese einem Zeitschlitzfeld in einem folgenden Rahmen nach einer Übertragungspausenzeitdauer, bei der keine Übertragungsdaten in den Zeitschlitzfeldern in speziellen Rahmen unter dem Strom der Rahmen, die vom Knoten B zur UE übertragen werden, existieren, zugewiesen werden, wobei das Verfahren die folgenden Schritte aufweist:

Messen eines ersten Ausbreitungsverlusts zwischen dem Knoten B und der UE durch das Empfangen der Leistungspegelinformation an einem spezifischen Zeitschlitz in der Übertragungspausenzeitdauer;

Detektieren eines Versatzes, der unter Berücksichtigung (i) der Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer verwendet wird, (ii) eines zweiten Ausbreitungsverlusts zwischen dem Knoten B und der UE im Zeitschlitz direkt vor der Übertragungspausenzeitdauer, (iii) eines TPC-Befehls, der vom Knoten B im Zeitschlitz direkt vor der Übertragungspausenzeitdauer in Abwärtsrichtung empfangen wurde, und (iv) einer Änderung in der Kanalumgebung zwischen dem Knoten B und der UE bestimmt wird; und

Bestimmen einer ersten Übertragungsleistung in Aufwärtsrichtung durch das Summieren (a) der Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer verwendet wird, (b) eines Werts, der durch das Subtrahieren des zweiten Ausbreitungsverlusts vom ersten Ausbreitungsverlust bestimmt wurde, und (c) des Versatzes.

5. Übertragungsleistungssteuerverfahren nach Anspruch 4, wobei es weiter folgende Schritte umfaßt:

Messen eines ersten Interferenzrauschens des Knotens B durch das Empfangen eines speziellen Kanalsignals, das vom Knoten B in einem spezifischen Zeitschlitz übertragen wird, während der erste Ausbreitungsverlust gemessen wird;

Messen eines zweiten Interferenzrauschens am Knoten B direkt vor der Übertragungspausenzeitdauer, nach dem Messen des ersten Interferenzrauschens; und

Bestimmen einer zweiten Übertragungsleistung in Aufwärtsrichtung durch das Summieren (i) der Übertragungsleistung in Aufwärtsrichtung, (ii) des Werts, der durch das Subtrahieren des zweiten Ausbreitungsverlusts vom ersten Ausbreitungsverlust bestimmt wird, (iii) des Versatzes, und (iv) eines Werts, der durch das Subtrahieren des zweiten Interferenzrauschens vom ersten Interferenzrauschen bestimmt wird.

6. Übertragungsleistungssteuerverfahren nach Anspruch 4, wobei es weiter die folgenden Schritte umfaßt:

Messen eines Interferenzrauschens am Knoten B durch das Empfangen eines speziellen Kanalsignals, das vom Knoten B im spezifischen Zeitschlitz übertragen wird; und

Bestimmen einer dritten Übertragungsleistung in Aufwärtsrichtung unter Berücksichtigung eines Werts, der durch das Summieren von (i) Werten, die durch das Anwenden eines Gewichts auf der Basis einer Länge der Übertragungspausenzeitdauer auf den aktuell gemessenen ersten Ausbreitungsverlust und eines mittleren Ausbreitungsverlusts zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer bestimmt werden, (ii) eines vorbestimmten Ziel-SIR, und (iii) einem Versatz für das Kompensieren des Ausbreitungsverlustfehlers und auch einer Berücksichtigung eines anderen Gewichts auf der Basis der Länge der Übertragungspausenzeitdauer für die erste Übertragungsleistung in Aufwärtsrichtung.

7. Übertragungsleistungssteuerverfahren nach Anspruch 4, wobei es weiter, wenn nur ein Zeitschlitz, der die Daten überträgt, einer Strahlformung unterworfen wird, den Schritt der Bestimmung einer vierten Übertragungsleistung in Aufwärtsrichtung durch das Summieren (i) einer Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer übertragen wird, (ii) eines Werts, der unter Berücksichtigung der Kompensation einer Ausbreitungsverlustdifferenz zwischen einem Zeitschlitzfeld, das einer Strahlformung unterworfen wird, und eines Zeitschlitzfeldes, das keiner Strahlformung unterworfen wird, und eines Werts, der durch das Subtrahieren des zweiten Ausbreitungsverlusts vom ersten Ausbreitungsverlust bestimmt wird, bestimmt wird, und (iv) des Versatzes umfaßt.

8. Übertragungsleistungssteuerverfahren nach Anspruch 5, wobei es weiter die folgenden Schritte umfaßt:

Messen eines Interferenzrauschens des Knotens B durch das Empfangen eines speziellen Kanalsignals, das vom Knoten B im spezifischen Zeitschlitz übertragen wird; und

Bestimmen einer fünften Übertragungsleistung in Aufwärtsrichtung unter Berücksichtigung eines Werts, der durch das Aufsummieren von (i) Werten, die durch das Anwenden eines Gewichts, das auf der Länge der Übertragungspausenzeitdauer basiert, auf den aktuell gemessenen ersten Ausbreitungsverlust und einen mittleren Ausbreitungsverlust zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer bestimmt werden, (ii) eines vorbestimmten Ziel-SIR, und (iii) eines Versatzes für das Kompensieren des Ausbreitungsverlustfehlers, und auch unter Berücksichtigung eines anderen Gewichts, das auf der Länge der Übertragungspause der zweiten Übertragungsleistung in Aufwärtsrichtung basiert, bestimmt wird.

9. Übertragungsleistungssteuerverfahren nach Anspruch 5, wobei es weiter, wenn nur ein Zeitschlitz, der die Daten überträgt, einer Strahlformung unterworfen wird, den Schritt der Bestimmung einer sechsten Übertragungsleistung in Aufwärtsrichtung durch das Summieren (i) einer Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer übertragen wird, (ii) eines Werts, der unter Berücksichtigung der Kompensation einer Ausbreitungsverlustdifferenz zwischen einem Zeitschlitzfeld, das einer Strahlformung unterworfen wird, und eines Zeitschlitzfeldes, das keiner Strahlformung unterworfen wird, und eines Werts, der durch das Subtrahieren des zweiten Ausbreitungsverlusts vom ersten Ausbreitungsverlust bestimmt wird, bestimmt wird, (iii)

des Versatzes, und (iv) eines Werts, der durch das Subtrahieren des zweiten Interferenzrauschens vom ersten Interferenzrauschen bestimmt wird, umfaßt.

10. Übertragungsleistungssteuerverfahren nach Anspruch 6, wobei der spezielle Kanal ein Funkübertragungskanal ist.

11. Übertragungsleistungssteuervorrichtung in einer UE für ein TDD CDMA Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder der Rahmen ein Feld, das den Leistungspegel der Information, die vom Knoten B übertragen wird, angibt, und einen Zeitschlitzfeld für das Zuweisen eines TPC-Befehls und der Übertragungsdaten vom Knoten B an die UE umfaßt, wobei die UE die Daten, die vom Knoten B übertragen werden, empfängt, wobei diese einem Zeitschlitzfeld in einem folgenden Rahmen nach einer Übertragungspausenzeitdauer, bei der keine Übertragungsdaten in den Zeitschlitzfeldern im speziellen Rahmen existieren, unter dem Strom von Rahmen, die vom Knoten B zur UE übertragen werden, zugewiesen sind, umfassend:

eine Übertragungsleistungssteuervorrichtung in Aufwärtsrichtung für das Messen eines Ausbreitungsverlusts zwischen dem Knoten B und der UE durch das Empfangen der Leistungspegelinformation, die in einem spezifischen Zeitschlitz in der Übertragungspausenzeitdauer empfangen wird, wenn eine Übertragungspause eines spezifischen Kanalsignals, das vom Knoten B empfangen wird, auftritt, das Detektieren eines Interferenzrauschens des Knotens B aus dem spezifischen Kanalsignal, und das Bestimmen einer Übertragungsleistung in Aufwärtsrichtung durch das Summieren von (i) Werten, die durch das Anlegen eines Gewichts, das auf der Länge der Übertragungspausenzeitdauer basiert, auf den aktuell gemessenen Ausbreitungsverlust und einen mittleren Ausbreitungsverlust zwischen dem Knoten B und der UE während der Übertragungspausenzeitdauer bestimmt werden, (ii) eines vorbestimmten Ziel-SIR, und (iii) eines Versatzes für das Kompensieren des Ausbreitungsverlustfehlers;

einen TPC-Befehlsgenerator für die Abwärtsrichtung für das Erzeugen eines TPC-Befehls für das Steuern der Übertragungsleistung in Abwärtsrichtung, die durch den Knoten B im folgenden Rahmen übertragen werden soll, durch das Empfangen der Übertragungsleistung in Aufwärtsrichtung, die durch die Übertragungsleistungssteuervorrichtung für die Aufwärtsrichtung bestimmt wird;

einen Multiplexer für das Multiplexen des TPC-Befehls in Abwärtsrichtung, von Benutzerdaten, die zum Knoten B übertragen werden sollen, und eines TFCI (Transport Format Combination Indicator, Transportformatkombinationsanzeigers), der einen Typ und eine Datenrate der Benutzerdaten bezeichnet;

und

einen Multiplizierer für das Multiplizieren des Kanalsignals in Aufwärtsrichtung mit einer Kanalverstärkung, basierend auf der bestimmten Übertragungsleistung in Aufwärtsrichtung.

12. Übertragungsleistungssteuervorrichtung nach Anspruch 11, wobei die Übertragungsleistungssteuervorrichtung für die Aufwärtsrichtung die Übertragungsleistung in Aufwärtsrichtung durch das Messen eines ersten Ausbreitungsverlusts zwischen dem Knoten B und der UE auf der Basis der Leistungspegelinformation, basierend auf einer Leistungspegelinformation, die in einem speziellen Zeitschlitz während der Übertragungspausenzeitdauer empfangen wird, Bestimmen eines Versatzes, basierend auf der Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer verwendet wird, eines zweiten Ausbreitungsverlusts zwischen dem Knoten B und der UE im Zeitschlitz direkt vor der Übertragungspausenzeitdauer, und eines TPC-Befehls, der vom Knoten B im Zeitschlitz direkt vor der Übertragungspausenzeitdauer empfangen wird, und einer Änderung in der Kanalumgebung zwischen dem Knoten B und der UE, und dem Summieren von (i) der Übertragungsleistung in Aufwärtsrichtung, die im Zeitschlitz direkt vor der Übertragungspausenzeitdauer verwendet wird, (ii) eines Werts, der durch das Subtrahieren des zweiten Ausbreitungsverlusts vom ersten Ausbreitungsverlust bestimmt wird, und (iii) des Versatzes, bestimmt.

13. Übertragungsleistungssteuervorrichtung eines Knotens B in einer UE für ein TDD CDMA Kommunikationssystem, das einen Strom von Rahmen von einem Knoten B zur UE überträgt, wobei jeder Rahmen ein Feld, das die Leistungspegelinformation, die vom Knoten B übertragen wird, anzeigt, und ein Zeitschlitzfeld für das Zuweisen eines TPC-Befehls und von Übertragungsdaten vom Knoten B zur UE einschließt, wobei der Knoten B Daten zur UE in einem folgenden Rahmen nach einer Übertragungspausenzeitdauer, bei der keine Übertragungsdaten in den Zeitschlitzfeldern in speziellen Rahmen existieren, unter dem Strom von Rahmen, die vom Knoten B zur UE übertragen werden, überträgt, umfassend:

einen Demultiplexer für das Demultiplexen eines Kanalsignals in Aufwärtsrichtung, das von der UE empfangen wird, in einen TPC-Befehl für die Abwärtsrichtung, der Benutzerdaten von der UE, und eines TFCI, der einen Typ und eine Datenrate der Benutzerdaten anzeigt;

eine Übertragungsleistungssteuervorrichtung für die Abwärtsrichtung für das Bestimmen der Übertragungsleistung in Abwärtsrichtung für die UE auf der Basis des TPC-Befehls für die Abwärtsrichtung, nach dem Auftreten einer Übertragungspause;

einen TPC-Generator für die Aufwärtsrichtung für das Erzeugen eines TPC-Befehls für die Aufwärtsrichtung für das Steuern der Übertragungsleistung in Aufwärtsrichtung, die zur UE im folgenden Rahmen übertragen werden soll, durch das Empfangen der Übertragungsleistung in Aufwärtsrichtung, die durch die Übertragungsleistungssteuervorrichtung für die Abwärtsrichtung bestimmt wurde;

einen Multiplexer für das Multiplexen des erzeugten TPC-Befehls, der Benutzerdaten, die zur UE übertragen werden sollen, und der TFCI, der einen Typ und eine Datenrate der Benutzerdaten anzeigt; und

einen Multiplizierer für das Multiplizieren des Kanalsignals in Abwärtsrichtung mit einer Verstärkung auf der Basis der bestimmten Übertragungsleistung in Abwärtsrichtung.

Hierzu 7 Seite(n) Zeichnungen

Nummer: DE 102 01 270 A1
Int. Cl.7: H 04 J 3/16
Offenlegungstag: 8. August 2002

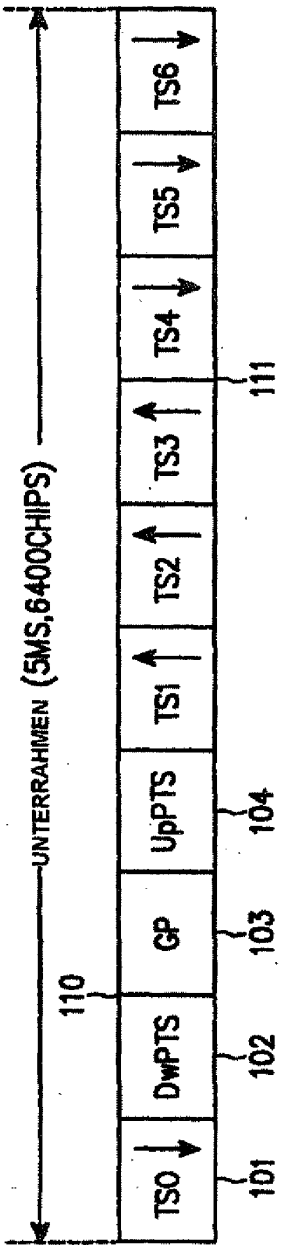


FIG. 1
STAND DER TECHNIK

Nummer: DE 102 01 270 A1
Int. Cl.[7]: H04J 3/16
Offenlegungstag: 8. August 2002

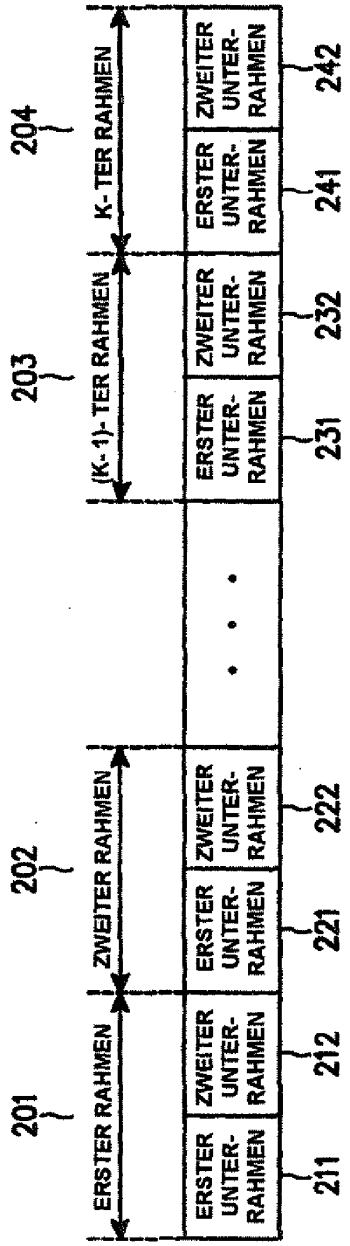


FIG.2
STAND DER TECHNIK

Nummer: DE 102 01 270 A1
Int. Cl.[7]: H 04 J 3/16
Offenlegungstag: 8. August 2002

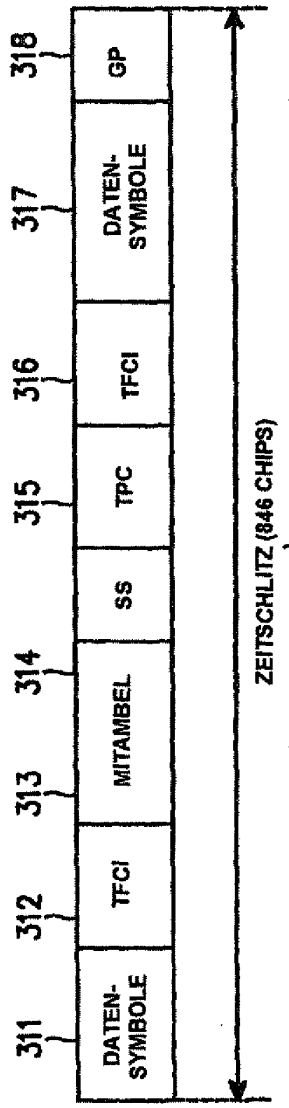


FIG.3
STAND DER TECHNIK

Nummer: DE 102 01 270 A1
Int. Cl.[7]: H 04 J 3/16
Offenlegungstag: 8. August 2002

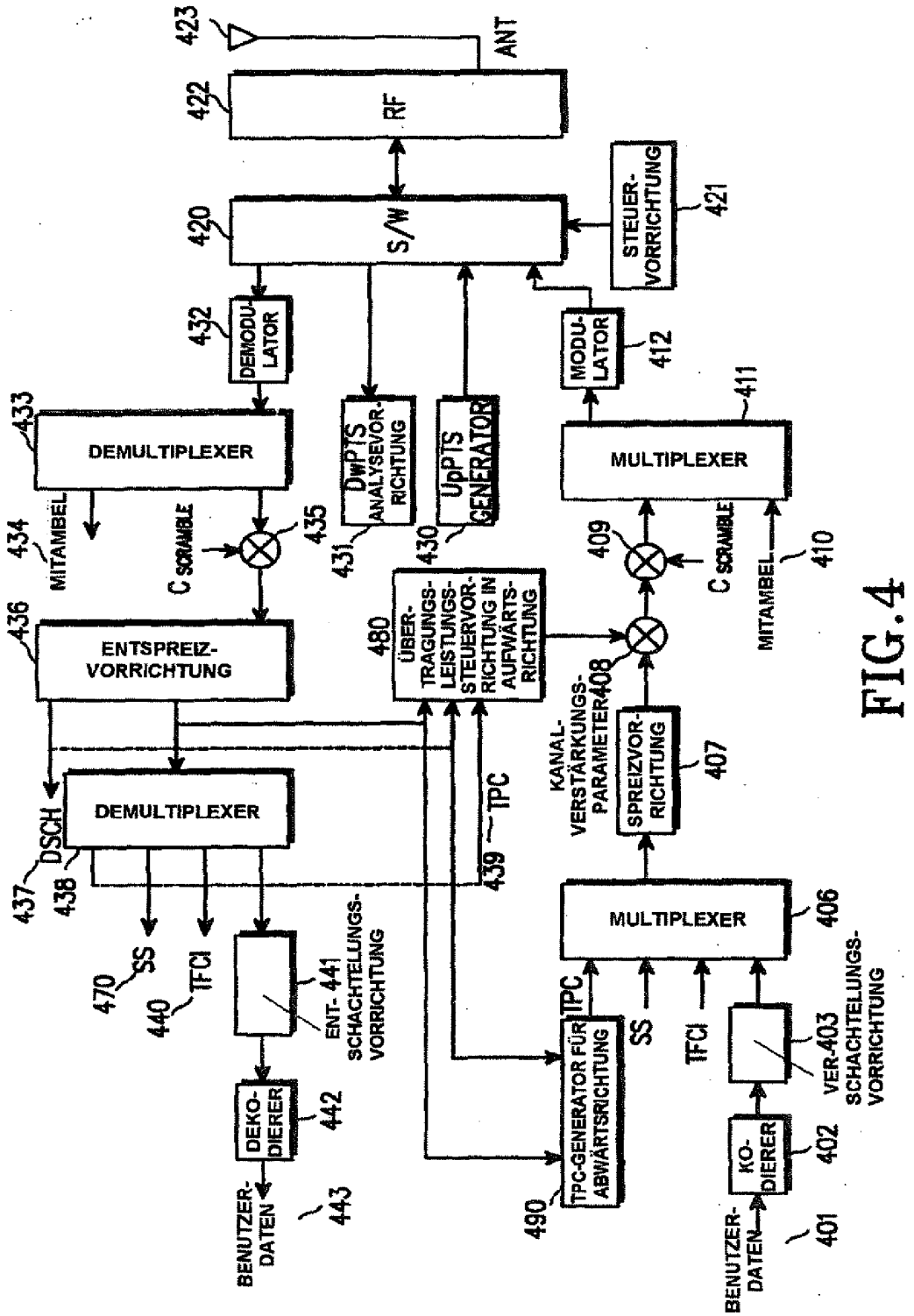


FIG. 4

102 320/575

Nummer: DE 102 01 270 A1
Int. Cl.7: H 04 J 3/16
Offenlegungstag: 8. August 2002

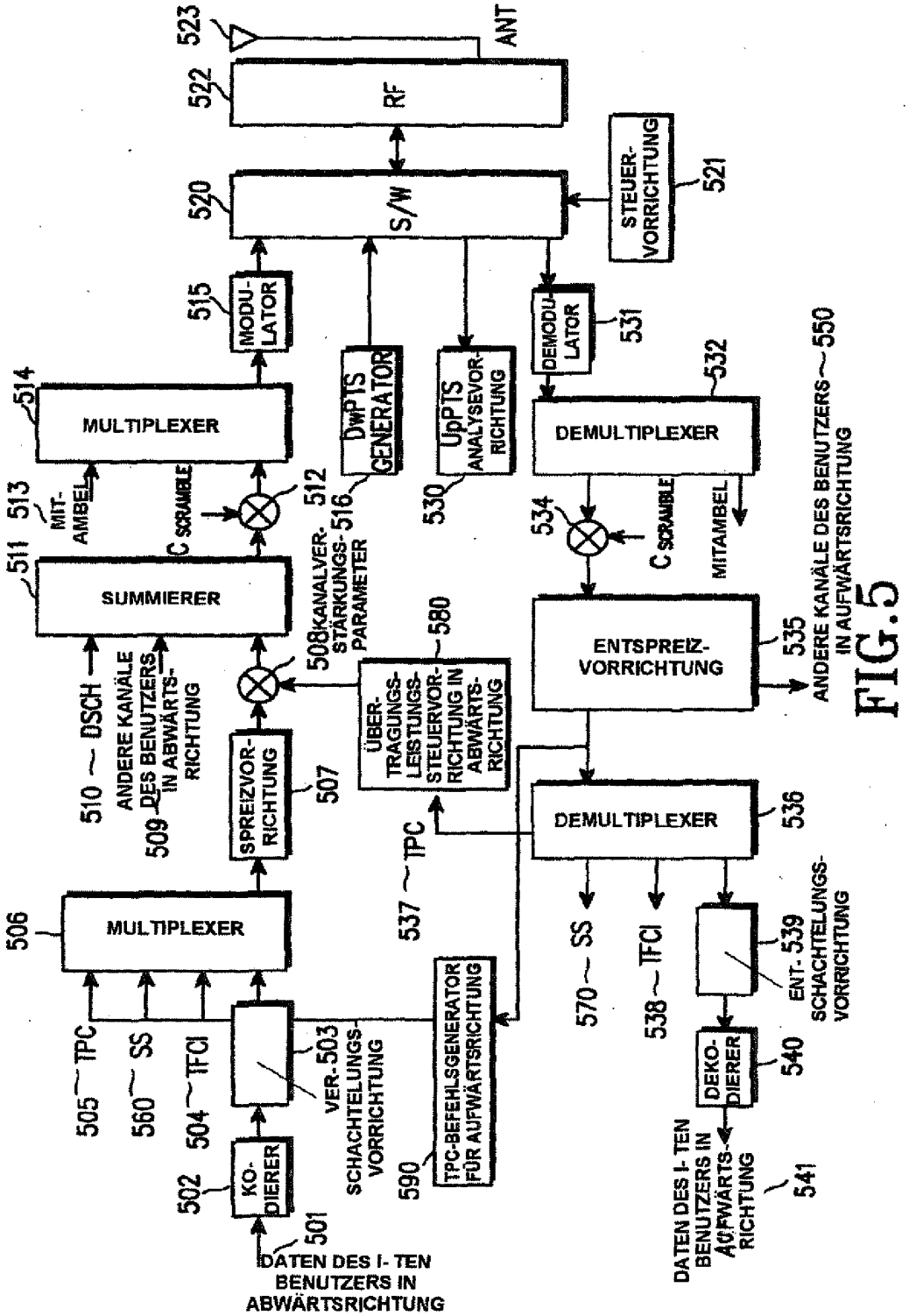


FIG.5

102 320/575

Nummer: DE 102 01 270 A1
Int. Cl.[7]: H 04 J 3/16
Offenlegungstag: 8. August 2002

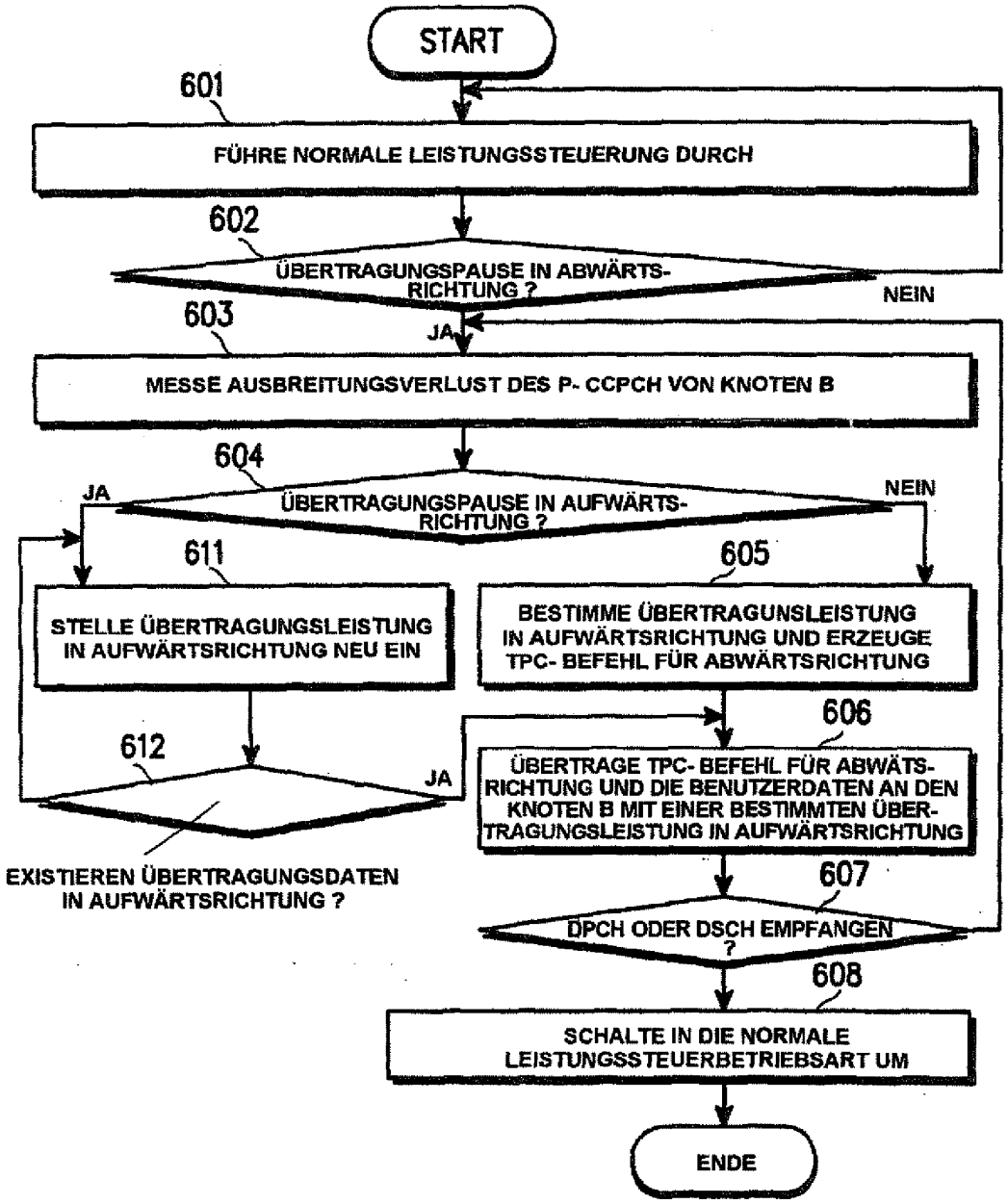


FIG. 6

Nummer: DE 102 01 270 A1
Int. Cl.[7]: H 04 J 3/16
Offenlegungstag: 8. August 2002

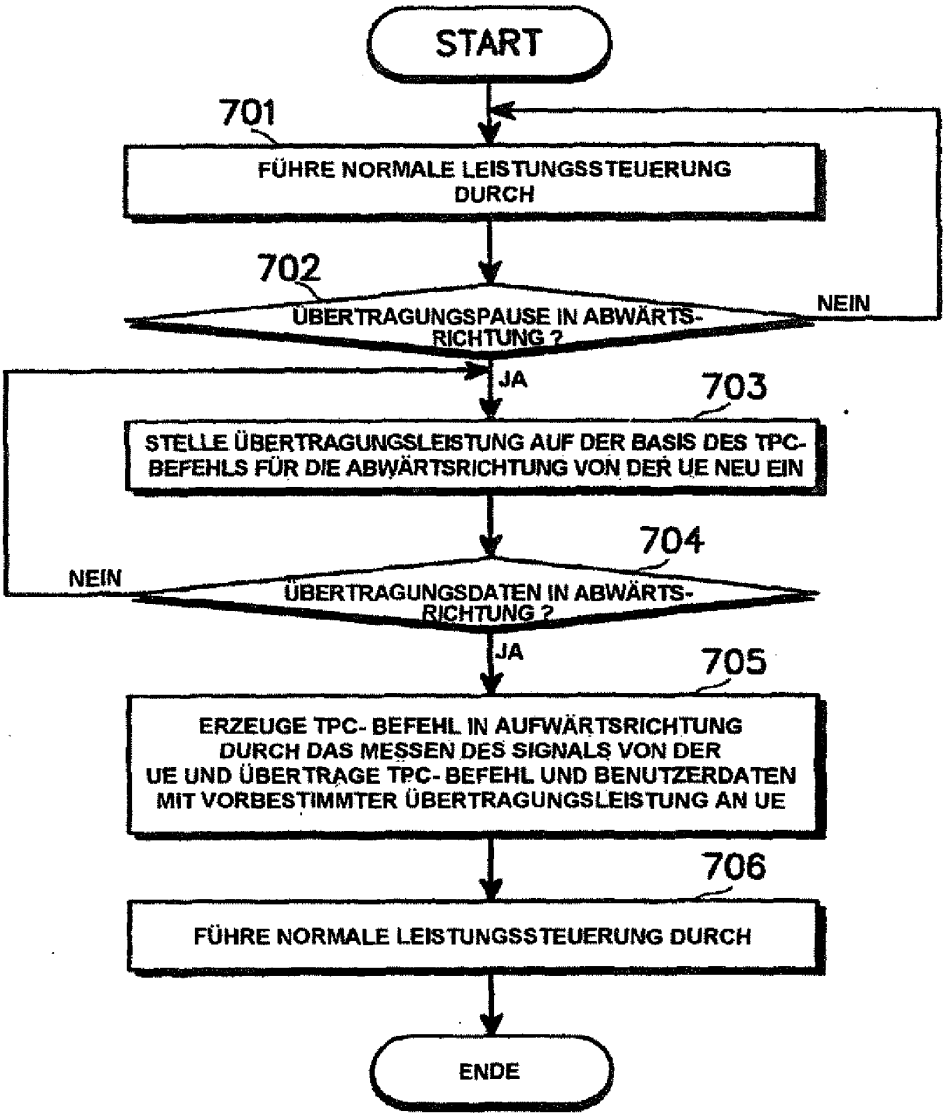


FIG. 7

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 467 582 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.10.2004 Bulletin 2004/42

(51) Int Cl.[7]: **H04Q 7/32**, H04Q 7/38

(21) Application number: **03008440.4**

(22) Date of filing: **11.04.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK RO

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(54) Method for synchronization in a mobile radio terminal

(57) A method for synchronizing measurements in a mobile communication apparatus having a first active radio access means (100) adapted to communicate according to a first radio access technology (RAT) and at least a second passive radio access means (200) adapted to communicate according to a second RAT. A time reference common to the first and the second access means (100) is generated. At least one time schedule is obtained, said schedule indicating at least one time gap wherein the second access means (200) is allowed to be active. The activation time of the schedule is based on the common time reference. An arrangement adapted to generate the common time reference and the time schedule is also disclosed.

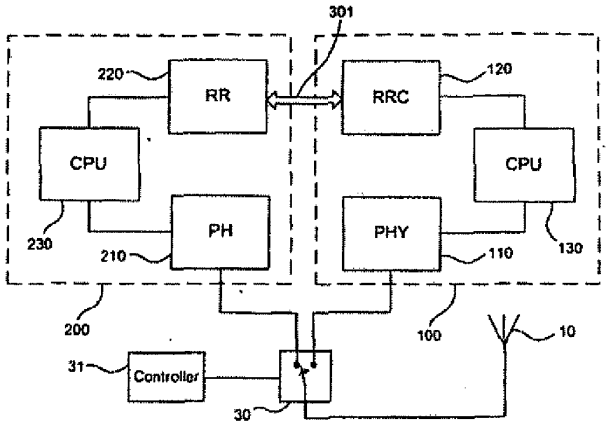


Fig. 2a

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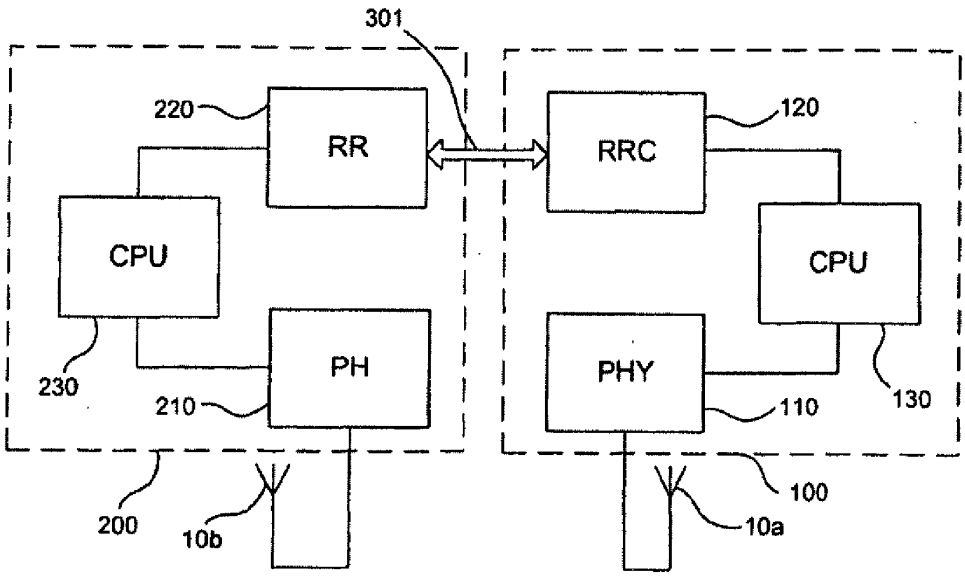


Fig. 2b

Description

Technical Field of the Invention

[0001] The present invention relates to a method for a mobile radio terminal having dual radio access technology (RAT) capabilities, and more specifically to a method for providing a common time event, from which the start time of measurements required according to respective RAT is determined, and a communication apparatus having such synchronization capabilities.

Description of Related Art

[0002] Different telecommunication systems using different technologies are available. GSM (Global System for Mobile communications) considered as a second-generation communication system is one of the most common and is based on TDMA (Time Division Multiple Access) radio access technology (RAT). GPRS (General Packet Radio Service) and EDGE (Enhanced Data for GSM Evolution) are data communication techniques for GSM systems, which are also based on TDMA technology. UMTS (Universal Mobile Telecommunication System) is considered a third-generation communication system and is based on WCDMA (Wideband Code Division Multiple Access) RAT. The WCDMA technology may be used as a stand-alone RAT. 3GPP (third Generation Partnership Project) specifications suggests a dual RAT communication system, which shall allow mobile terminals to handle both WCDMA and a second RAT, such as GSM. An important feature in dual RAT systems is the possibility to do handover between RATs and to select cell in the RAT that has the best radio environment quality. In order to achieve this, a dual RAT mobile terminal needs to execute cell measurements on both RAT systems in addition to receive/transmit using one of the RATS. When the terminal is connected to one system being active, measurements on the passive system have to be supported. This is a problem in case the passive system can not carry out measurements while the active system is receiving/transmitting. Simultaneous activities of the systems are problematic when the systems utilize common radio resources, such as a common antenna. Furthermore, simultaneous activities may also be problematic when two parallel RAT systems having separate radio resources are provided. A first of the parallel systems may interfere with the second RAT system to such an extent that the second RAT system is unable to provide measurements. In both these cases, the measurements on the passive system could be carried out when there are gaps in the reception/transmission of the active system. The occasions that can be utilized by the passive system are either determined by the active system or given by the radio access network of the active system.

[0003] There is a problem with providing measurements in a passive or slave system when it may not be active simultaneously with the active system, as the time gaps when the active system is not receiving/transmitting are very short. The passive system has to execute its measurements during such gaps. Furthermore, the two systems are not synchronized and may not use the same time format. Different time formats cause further problems, as is the case for GSM/GPRS/EDGE and WCDMA. According to GSM requirements, cell measurements have to be provided during pre-specified occasions that are determined in the GSM time format. It is not required that the cell measurements according to WCDMA RAT are executed during a specific time. WCDMA cell measurements may be executed at practically any time and do not have to be planned in advance, as is the case for GSM measurements. The time formats of GSM and WCDMA are different. Therefore, the WCDMA system cannot simply indicate in its own time format to the GSM system when the GSM system is allowed to be active and provide cell measurements, as the GSM system is not capable of interpreting the given gaps.

Summary of the Invention

[0004] One object of the present invention is to provide a method for providing a time schedule for cell measurements on an active radio access network utilizing a first radio access technology (RAT) and on a passive radio access network utilizing a second RAT, for facilitating e.g. handover and cell selection when the access means may not transmit/receive simultaneously.

[0005] According to a first aspect of the invention, this object is achieved by a method providing synchronization of the time used for cell measurements of a first communication network executed by a first radio access means and the time used for cell measurements of a second network executed by a second radio access means. The first access means utilizes a first RAT, such as WCDMA, whereas the second access means utilizes a second RAT, such as GSM. The first and the second access means may have one radio resource in common, which requires that the first and the second access means are not active simultaneously. Alternatively, the first and second access means have no radio resource in common, but are not allowed to transmit/receive simultaneously. According to the invention, the first access means is normally active and facilitates both communication and measurements, whereas the second access means acts as a slave access means, which only provides cell measurements until handover is made. According to the in-

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vention, a time reference common to the first and the second access means is generated. A time schedule common to the first and second access means is obtained, which indicates at least one time gap wherein the first access means is not receiving/transmitting and wherein the second access means is allowed to be active (receive/transmit). The schedule is determined based on the common time reference.

[0006] The common time reference may be generated in response to a time event (CTE) common to the first and second access means. In response to said CTE, the values of counters of the first and second access means, respectively, will be stored in counter value registers connected to the counters. The values of the registers will serve as the values of the time reference, which are expressed in the time format of the respective RAT.

[0007] The first access means will determine a measurement gap schedule (MGS) comprising a time schedule defining the duration and location of the gaps with respect to the CTE. The second access means is allowed to be active during said gaps. The MGS will comprise an activation time of the schedule, which is determined in the time format of the first access means and which may be determined based on the time distance from the CTE. When the second access means receives the MGS it may translate it and use the time reference of its registers to determine the activation time in its own time format.

[0008] Another object of the invention is to provide an arrangement adapted to provide cell measurements on an active radio access network utilizing a first radio access technology (RAT) and measurements on a passive radio access network utilizing a second RAT.

[0009] According to a second aspect of the invention, this object is achieved by an arrangement comprising a first radio access means and a second radio access means. The first access means is adapted to communicate with a first communication network according to a first RAT, whereas the second access means is adapted to communicate with a second communication network according to a second RAT. The arrangement further comprises a time reference generating means for generating a time reference common to the first and the second access means. A time schedule generating means for obtaining at least one time schedule being common to the first and second access means is adapted to generate a time schedule, which indicates at least one time gap wherein the first access means is not receiving/transmitting and wherein the second access means is allowed to be active. The time schedule generating means is further adapted to determine an activation time of the schedule, which is determined based on the time distance to the common time reference.

[0010] The first and second access means may have at least one common radio resource, such as an antenna.

[0011] The arrangement may further comprise in each access means a counter for generating counter values, a counter value register for registering counter values, and a counter synchronize mechanism. Either of the mechanisms may be adapted to generate a CTE, in response to which the counter values will be registered in the respective registers. The counter values are expressed in the time format of the respective access means.

[0012] The time schedule generating means may further be adapted to incorporate into the time schedule parameters identifying the time gaps, wherein the second access means is allowed to be active, and the activation time of the schedule. The second access means is adapted to translate the MGS to its own time format and determine the activation time by means of the counter values stored in its register.

[0013] According to a third aspect of the invention, a computer program product directly loadable into a memory of a mobile terminal having computer capabilities, such as a central processing unit for executing computer software code portions is disclosed. The product comprises software code portions for performing the method according to the invention when said product is run by said terminal.

[0014] According to a fourth aspect of the invention, the inventive arrangement is used in a wireless communication apparatus. The apparatus may be a mobile radio terminal, a mobile telephone, a pager, or a communicator, i.e. a personal digital assistant or a smartphone.

[0015] One advantage of the invention is that it gives a robust method that can be applied in all different states to transfer occasions for measurements from the active radio access means to the passive access means.

[0016] Further embodiments of the invention are defined in the dependent claims.

[0017] It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Brief Description of the Drawings

[0018] Further objects, features, and advantages of the invention will appear from the following description of several embodiments of the invention, wherein various aspects of the invention will be described in more detail with reference to the accompanying drawings, in which:

Fig.1 is a schematic front view of a mobile telephone and the environment in which it operates;
Fig. 2a is a block diagram of access means for a first and a second radio access technology having common radio

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resources;

Fig. 2b is a block diagram of access means for a first and a second radio access technology having separate antennas;

Fig. 3 is a more detailed block diagram of the access means of Fig. 2a and 2b;

Fig. 4 is a structure diagram showing a compressed mode pattern structure;

Fig. 5 is a timing diagram showing the relationship between the common time event, the activation request and the activation time of the compressed mode pattern of Fig. 4;

Fig. 6 is a flowchart of the steps of a method for the common time event;

Fig. 7 is a flowchart of a first embodiment of the steps of a method for the measurement gap schedule; and

Fig. 8 is a flowchart of a second embodiment of the steps of the method for the measurement gap schedule.

Detailed Description of Embodiments

[0019] Fig. 1 illustrates a mobile telephone 1 as a schematic front view and the environment in which it operates. The mobile telephone 1 comprises an antenna 10 mounted on the housing of the apparatus. Alternatively, the mobile telephone 1 may have an internal antenna mounted within the housing of the apparatus. The antenna 10 is electrically connected to a printed circuit board of the mobile telephone 1 through an antenna switch, as will be further described below. The mobile telephone further comprises a display 11, a keypad 12, a loudspeaker 13, and a microphone 14, which together provide a man-machine interface for operating the mobile telephone 1.

[0020] The mobile telephone 1 may alternatively have two separate internal or external antennas (se Fig. 2b) antennas, which are adapted to the radio access technology for which they are utilized, as will be discussed below.

[0021] The mobile telephone 1 is adapted to establish a first wireless link 15 to a radio station (base station) 16a of a first mobile telecommunication network 17. The mobile telephone 1 is also adapted to establish a second wireless link 18 to a radio station (base station) 19a of a second mobile telecommunication network 20. Each base station 16a, 19a serves one or several cells. The first system 17 utilizes a first radio access technology (RAT), such as WCDMA (Wideband Code Division Multiple Access) or cdma2000 (Code Division Multiple Access 2000), for communicating with the mobile telephone 1. The second system 20 utilizes a second radio access technology (RAT) other than the first RAT for communicating with the mobile telephone, such as GSM (Global System for Mobile communications).

[0022] The mobile telephone 1 is further adapted to select whether to utilize the first or the second communication network 17, 20 for providing communication of e.g. speech and data depending on the quality of the link 15, 18 between the base stations 16a, 19a and the mobile terminal 1. Thus, the mobile telephone has to provide cell measurements of neighboring cells. As is illustrated in Fig. 1, the first and the second network comprise several base stations 16b, 16c, and 19b, 19c, respectively, each serving one or several cells. As the position of the mobile telephone may change it may come into the vicinity of another cell, in which better link quality is provided compared to the one in which the mobile telephone 1 is located. Either the first or the second network 17, 20 is the active network, whereas the other is the passive or the slave system. When the mobile telephone 1 experiences superior link quality from a base station 16a-c, 19a-c, serving a specific cell not belonging to the active network 17, 20, the network may do handover to the other network. Also, the mobile may provide cell selection between neighboring cells within the same network. Handover and cell selection require that the mobile telephone provides cell measurements of both the active and the passive network, 17, 20.

[0023] The present invention provides a method for synchronizing the cell measurements of the active and the passive network when said networks are not utilizing the same time format. In WCDMA, frame, slot and chip are used as the time format, whereas the time format of GSM is multiframe and quarter bit.

[0024] The mobile telephone 1 may utilize common radio resources for communication according to the first and the second RAT. Thus, the antenna 10 is adapted to communicate signals in a first frequency band when the first network 17 is active and communicate signals in a second frequency band when the second network 20 is active. Communication using the WCDMA RAT is provided in the 2 GHz frequency range, whereas communication using the GSM RAT is provided in the 900, 1800, and/or 1900 frequency ranges.

[0025] As can be seen in Fig. 2a, the antenna 10 is connected to an antenna switch 30 for connection to either access means 100 of the first RAT or access means 200 of the second RAT, which may be provided as ASIC's (Application Specific Integrated Circuit) on separate chips. The switch 30 is controlled by a controller 31, which may be provided as an integrated circuit integral with the switch 30, or by any central processing unit (CPU) of the mobile telephone 1, as will be discussed below.

[0026] Alternatively, each access means 100, 200 has its own antenna, as can be seen in Fig. 2b. Corresponding components of Figs. 2a and 2b are denoted with the same reference numerals. In the embodiment of Fig. 2b, the first access means 100 is connected to a first antenna 10a, which is adapted to provide signals in at least a first frequency band, such as in the WCDMA frequency band. The second access means 200 is connected to a second antenna 10b, which is adapted to provide signals in at least a second frequency band, such as a GSM frequency band.

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[0027] The access means 100, 200, comprise circuitry for communicating according to their respective technologies. Each access means 100, 200 comprises an air interface stack having a physical layer implemented using hardware, and higher layer implemented with software for controlling the communication. The access means is generally known in the art and is therefore not further disclosed here, except when the invention departs from what is generally known.

[0028] For convenience, in the following the access means 100 adapted according to WCDMA RAT will be denoted WCDMA RAT 100 and the access means 200 adapted according to GSM RAT will be denoted GSM RAT 200. However, this should not be taken as limiting the scope of the invention, but is only for exemplifying purposes. The first communication may alternatively be a cdma2000 network and the second network may alternatively be a PCS network.

[0029] The switch 30 is in a first position operatively connected to a physical layer 110 of the air interface access stack of the WCDMA RAT 100. The WCDMA physical layer 110 is controlled by a radio resource controller (RRC) block 120, which may also control the switch 30. The RRC block 120 may establish and terminate a connection to the WCDMA system, as well as initiating cell measurements required according to system requirements and do handover. In a second position, the switch is operatively connected to the physical layer 210 of the air interface access stack of the GSM RAT 200. The GSM physical layer 210 is controlled by a management physical layer or radio resource (RR) block 220. The RR block 220 may establish and terminate a connection to the GSM system, as well as initiating cell measurements required according to system requirements and do handover. The RR block 220 may control the switch 30 instead of the RRC block 120. The circuits of the physical layer of the respective RAT's are connected via a first connection 300 (see Fig. 3) for purposes that will be described below. Also, a second connection 301 is provided between the higher layers (layer 2 and layer 3) of the access stacks of the respective RATs 100, 200, for providing high level communication, as will be further described below. Each RAT 100, 200 comprises a central processing unit 130, 230 for executing the functionality of the software that implements the higher layers of the access stacks.

[0030] Fig. 3 illustrates a more detailed block diagram of the mobile telephone 1 and components of the two RATs 100, 200. The WCDMA physical layer 110 comprises a transceiver 150 for transmitting and receiving signals according to WCDMA technology when connected to the antenna 10 via the switch 30. A timing generator 155, for providing a time reference generating means, is adapted to generate a time reference in response to a time event in the time format of the WCDMA RAT. The timing generator 155 may be implemented as an integrated circuit of the ASIC. The timing generator 155 comprises a counter synchronize mechanism 156, which is adapted to generate a synchronization signal, common time event (CTE), which will synchronize a counter 158 of the WCDMA RAT, as will be described below. When the CTE is generated by the counter synchronize mechanism 156 the timing generator 155 will store counter values specific to the WCDMA RAT in a counter value register 157. The register 157 is readable from software executed in a CPU 130, which is specific to the WCDMA RAT 100. A synchronize mechanism 161, e.g. implemented by software instructions run on the CPU 130 or a separate processor (not shown), is adapted to generate a real time event shared between the RATs 100, 200, which indicates that an activation request to initiate measurements has been issued. This function will generate maskable interrupts in both RATs, which will synchronize the measurement initiation and activate the scheduling of the measurements. A high speed serial link (HSSL) interface 162 for communicating data between the WCDMA RAT 100 and the GSM RAT 200 is connected to the CPU 130. Parameters for a measurement gap schedule (MGS) defining the time schedule will be transmitted via the HSSL 162 over a connection 301a, which may be implemented as a serial connection. A memory 153 is connected to the CPU 130, and may be provided as a combined random access memory (RAM) and read only memory (ROM) integrated on the ASIC. The memory 153 may comprise software code portions for providing computer readable instructions for carrying out software implemented features of the invention when run by the mobile telephone 1. The CPU 130 may serve as a means for carrying out said instructions.

[0031] The GSM physical layer 210 comprises transceiver circuitry 250 for exchanging data with the antenna 10 when the switch 30 is in a second position. Similar to the WCDMA RAT 100, the GSM RAT 200 comprises a timing generator 255, for providing a time reference generating means, according to the same principles as the WCDMA timing generator 155. The timing generator 255 comprises a counter synchronize mechanism 256, a counter value register 257, and a counter 258. The counter synchronize mechanism 256 is connected to the counter synchronize mechanism 156 of the WCDMA RAT. A CPU 230, which is specific to the GSM RAT is connected to the timing generator 255 and the transceiver circuitry 250. The transceiver circuitry is adapted to provide communication according to GSM RAT. A synchronize mechanism 261 is adapted to provide synchronization for the measurement activation and may be implemented by computer readable software instructions executable by the CPU 230 or a separate processor. The synchronize mechanisms 161, 261 of the respective RAT 100, 200 may exchange data, which is indicated by a connection 301b. A HSSL interface 262 connected to the GSM CPU 230 is adapted to exchange data with the HSSL interface 162 of the WCDMA RAT 100 over the connection 301a. A memory 253 is connected to the CPU 230, and may be provided as a combined random access memory (RAM) and read only memory (ROM). The memory 253 may comprise software code portions for providing computer readable instructions for carrying out software implemented features of the invention when run by the mobile telephone 1. The CPU 230 may serve as a means for carrying out said instructions.

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[0032] Each RAT 100, 200 is in operation required to provide cell measurements on its respective communication network 17, 20. The measurement requirements of the WCDMA RAT 100 when it is active may be measurements on neighboring cells, inter-frequency measurement, received signal code power, received signal code power after radio link combination, SIR (Signal-to-Interference Ratio), RSSI (Received Signal Strength Indicator), etc. Similarly, there are requirements that the GSM RAT 200 in operation should provide cell measurements, although it is the passive slave RAT. Such measurements comprise e.g. RSSI for a number of different neighboring cells, identification measurement, and reconfirmation measurement. Whenever a cell having superior radio link quality is found, handover from the active to the passive network may be made.

[0033] Interrupts for GSM measurements can be provided in three different categories; interrupt during compressed mode; interrupt during measurement occasions; and interrupt during measurement DRX cycle. Here, interrupt means a temporary suspension of an ongoing process caused by an event outside that process. A number of MGS schedules, as e.g. illustrated in Fig. 4, can be run in parallel. A request to activate each schedule may be issued separately. The activation time of each schedule may be determined with regard to one and the same CTE as illustrated in Fig. 5. Alternatively, each time schedule will have an activation time that is determined with regard to a specific CTE, which is independent of the CTE connected to any other time schedule.

[0034] The MGS according to the invention is a mechanism comprising time schedule parameters for synchronizing the required WCDMA and GSM measurements when the GSM RAT is passive. The available time gaps, wherein the WCDMA RAT is not receiving/transmitting, are determined and indicated by the WCDMA RAT 100. The WCDMA RAT may be in two different RRC (Radio Resource Control) protocol statuses: Idle mode and UTRAN connected mode. In idle mode, measurements are provided according to the discontinuous reception (DRX) cycle. The UTRAN connected mode comprises Cell_PCH, Cell_FACH, Cell_DCH and URA_PCH.

[0035] In Cell_DCH, a DPCH (Dedicated Physical Channel) is assigned to the user equipment (UE), which may be a mobile telephone 1. The UE has identified the cell level by the current Active Set, which is a procedure for updating the active set of communication parameters of the connection between the UE and the UTRAN. The dedicated transport channel, the downlink-shared transport channel and the combination thereof have also been identified.

[0036] In Cell_FACH no DPCH is assigned to the UE. In this state, the UE receives FACH (Forward Access Channel) messages in the downlink, and in the uplink it can use a common channel that can execute transmission from time to time according to access procedures of each transport channel. UTRAN is aware of the location of the UE at cell level (the cell updated by UE most recently).

[0037] In Cell_PCH, URA_PCH and Idle mode, no dedicated channel is assigned to the UE. In the downlink, the UE receives PCH messages via PICH (Paging Indication Channel) by DRX. In the uplink, the UE is not engaged in anything. UTRAN is aware of the location of the UE at UTRAN registration level (the URA (User Registration Area) assigned most recently to the UE during URA Update in Cell_FACH state).

[0038] When the WCDMA RAT is in idle state the DRX cycle will control how often and how much the GSM RAT 200 is allowed to operate. In Cell_FACH the gaps are called measurement occasions in the downlink and some of them are allocated for GSM use. In the uplink, the mobile telephone 1 may itself determine when to transmit. These gaps will never be shorter than 1 WCDMA frame and thereby clearly exceed the 14 WCDMA slot maximum gap allocated in compressed mode. It is required that the GSM system manage to measure RSSI for 16 different neighboring cells in 10ms, which gives 652 µs for each carrier that e.g. can be split into one measure part that is 59 ps (16 GSM symbols) and a tuning part that is 566 µs.

[0039] In Fig. 4, wherein the compressed mode pattern structure is illustrated, the following abbreviations are used:

TGSN	Transmission Gap Starting Slot Number;
TGL1	Transmission Gap Length 1, duration of the first transmission gap within the TGP (Transmission Gap Pattern) expressed in slots;
TGL2	Transmission Gap Length 2, duration of the second transmission gap within the TGP (Transmission Gap Pattern) expressed in slots; if not used in a pattern TGL2=TGL1;
TGD	Transmission Gap start Distance, which is the duration between the starting slots of two consecutive transmission gaps within a TGP expressed in slots. If only one TGL is used, this will not be used;
TGPL1	Transmission Gap Pattern Length 1 is the duration of transmission gap pattern length 1 expressed in number of frames;
TGPL2	Transmission Gap Pattern Length 2 is the duration of transmission gap pattern length 2, if used, expressed in number of frames;
TGPRC	Transmission Gap Pattern Repetition Count is the number of transmission gap patterns within the transmission gap pattern sequence

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(continued)

TGCFN	Transmission Gap Connection Frame Number (TGCFN) is the Connection Frame Number (CFN) of the first pattern 1 within the transmission gap pattern sequence.

[0040] Fig. 4 illustrates the compressed mode pattern structure wherein reception/transmission gaps may occur. Compressed mode is based on that the radio transmission and reception of the WCDMA signals are turned off during small intervals to allow measurements on GSM neighboring cells. The transmission gaps in the compressed mode structure are referenced to the WCDMA frame and slot structure. When the WCDMA RAT 100 uses compressed mode it will raise the hardest requirements on the GSM radio, as it provides the shortest gaps. The transmission gap length (TGL) can be 3, 4, 5, 7, 10, and 14 WCDMA slots where 3 and 4 are only used for RSSI measurements, 5 is used only when the GSM cell's timing is known, and 7, 10, or 14 are used for previously not identified cells. Corresponding patterns may be provided for measurement occasion and DRX cycle having gaps wherein the WCDMA RAT 100 is not receiving/transmitting.

[0041] The transmission gap can be placed in one frame. Alternatively the transmission gap crosses the frame boarder. In order to allow efficient measurements, several intervals may be placed within a transmission gap pattern (TGP).

[0042] There are three different measurement patterns for GSM with three different purposes, GSM RSSI measurements, and GSM BSIC identification and reconfirmation. Each pattern has specific requirements. Therefore, the RR block 220 needs information of the available gaps to be able to plan the future measurements. Once the gaps are known the RR block 220 may plan the measurements based on the available gaps.

[0043] The effective transmission gap may be smaller than the TGL due to two factors: the power mask for the uplink (UL) and the timing offset between the UL and downlink (DL). The WCDMA transmitter power mask surrounding the compressed mode gap introduces a margin at the start of the gap and the end of the gap. Since the start of the transmission gap will be used for radio tuning, the margin at the start will not affect the dual RAT operation but the margin at the end will disable the last portion of the transmission gap to be used for dual RAT operation. The most rigid requirement on the GSM radio tuning is the case with TGL 14 and GSM RSSI measurements. In order to get some margin it is preferred to require a radio settling time for the GSM radio. The margin has to be evaluated and tested for each particular case.

[0044] The WCDMA RAT 100 first determines the specific transmission gaps that are required for its own measurements. Any remaining transmission gap may be allocated for measurements made by the GSM RAT 200. Alternatively, the gaps that should be handed over are pre-specified, wherein the WCDMA RAT 100 has to adapt its measurements. The WCDMA RAT 100 provides to the GSM RAT 100 the position of the gaps having reference to the CTE, and a specified activation time. The basic idea is that the activation time of the transmission gap pattern is related to the latest CTE. Considering that an activation start of the pattern is related to the CFN (connection frame number), the request to activate the measurement pattern needs to be sent down from RRC block 120 to the timing generator 155 of the WCDMA physical layer 110 no more than one CFN period in advance of the activation start time. One CFN period corresponds to 25*10 ms. The request to activate the pattern may serve as the event that initiates the generation of the CTE and the MGS. Due to that the CTE could be placed at any chip position, the following parameters need to be registered in the counter value register 157 of the WCDMA RAT 100 at the time of the CTE:

- The current connection frame number: $CFN_{CTE} \in \{0 \ldots 255\}$
- The current slot: $Slot_{CTE} \in \{0 \ldots 14\}$
- The current chip: $Chip_{CTE} \in \{0 \ldots 2559\}$

The CFN is not valid in idle mode, wherein the SFN (cell System Frame Number) has to be used to calculate the correct gaps.

[0045] A measurement activation request may cause a request for a CTE signal to be sent between the timing generators 155, 255, wherein the counter values will be stored in their counter registers 157, 257, as will be discussed below. The values of the WCDMA counter 158 and the GSM counter 258 will be stored approximately simultaneously, i.e. sufficiently simultaneous for providing a common time reference, as the RATs 100, 200 may run on asynchronous clocks. The parameters registered in the GSM RAT 200 are:

- The current frame number (FN) in the GSM multiframe structure $\in \{0 \ldots 51\}$;
- The position within the current frame $\in \{0 \ldots 4999\}$ [GSM quarter bit (QB)].

Alternatively, the complete representation of the frame number in the GSM stack is registered, which is in the range of [0...2715647].

[0046] In total, three different GSM related compressed mode patterns, or any other pattern where appropriate,

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should be able to be configured to take care of the different GSM measurement requirements. This requires that the activation start of all three patterns need to refer to the same CTE. The relationship between the CTE, the measurement activation request and the activation time of the compressed mode patterns is illustrated in Fig. 5. Similar patterns may be specified for any other possible pattern, such as Idle mode and measurement occasion patterns. The configuration of activation time can be done for all patterns at once or pattern by pattern. The distance between the CTE and each activation time is denoted as $Chip_{CTE\_active\#\_delta}$, wherein #=1..3 in Fig. 5. The $Chip_{CTE\_active\#\_delta}$ is based on the sum of the distance between the CTE and the CFN when the activation is requested, (CFN_{req}), and the remaining distance between the CFN_{req} and the TGCFN.

[0047] Due to the time delay, which is caused by path drift of the received signals compared to the internal clock of the WCDMA RAT 100, between the channel timing and the counter 158 of the WCDMA RAT 100 a delay term T_{CTE_ALIGN} expressed in chips may be introduced to improve the accuracy of the time schedule, where:

$$T_{CTE\_ALIGN}=T_{channel\_delay}+T_{CTE}\ [chip];$$
$$T_{CTE}=Chip_{CTE}-Slot_{CTE}*2560\ [chip];\ and$$
$$T_{channel\_delay}=path\ delay \in \{0...38399\}\ [chip].$$

[0048] Path delay is the chip timing reference for the downlink DCH. $Chip_{CTE}$ and $Slot_{CTE}$ are the chip and slot, respectively, in which the CTE is executed.

[0049] Each of the distances from the CTE to the activation time expressed in chip may be calculated as:

$$Chip_{CTE\_req\#\_delta}=T_{CTE\_ALIGN}+(REP_{256}+mod_{CFN}(CFN_{req}-CFN_{CTE}, 256))*15*2560;$$
$$Chip_{req\_active\#\_delta}=mod_{CFN}(TGCFN-CFN_{req}, 256))*15*2560$$
$$Chip_{CTE\_active\#\_delta}=Chip_{CTE\_req\#\_delta}$$
$$+Chip_{req\_active\#\_delta}+TGSN*2560;$$

where mod_{CFN} is a modulo 256 function and REP_{256} is the counter 158 of the WCDMA RAT 100 that starts at 0 and is updated each time the CFN is equal to the CFN_{CTE}. As the first activation request is made before the CTE, the CFN_{req} shall be set to CFN_{CTE} for the calculation of the first distance $Chip_{CTE\_activ1\_delta}$.

[0050] The counter parameters in the WCDMA RAT 100 are expressed in WCDMA time format, whereas the counter parameters in the GSM RAT 200 are expressed in GSM time format. The WCDMA RAT 200 is the active RAT, and therefore all arithmetic operations should be made in chips to avoid summation and truncation errors. Therefore, it is necessary for the GSM RAT 200 to convert the values of the parameters determined by the WCDMA RAT 200 into QB, which is made by multiplying each parameter with the quota 325/1152.

[0051] The parameters of the MGS will define a common time schedule for providing the GSM and WCDMA measurements, and may comprise:

Schedule ID (SI) ∈ {1...6} :

[0052] This parameter identifies the schedule, which will be needed in those situations when more than one schedule are active simultaneously. The value for this parameter is given by the Transmission Gap Pattern Sequence Identifier (TGPSI ∈ {1...6} in compressed mode). In other states there will only be one schedule running at the same time, i.e. one value for the SI.

Schedule Start Time (SST) ∈ {0...2^{32}-1} [chip] :

[0053] This parameter sets the activation time for a schedule in relation to the common time reference that is shared between the WCDMA RAT 100 and the GSM RAT 100 as a common time event (CTE). SST is pointing at the first gap occurrence, as is indicated in Fig. 4. The 32-bit range permits a time range up to 18 minutes and 38 seconds. This range is, however, for exemplification and has to be tested and evaluated in each particular case.

Schedule Transmission Gap Pattern Length 1 and 2 (STGPL1 and STGPL2) ∈ {0...19660800} [chip] :

[0054] STGPL1 sets the distance between the starting point of TG1 in pattern 1 and pattern 2 (or STGPL1 in the next pattern if no pattern 2 is defined). STGPL2 sets the distance between the starting point of TG1 in pattern 2 and pattern 1. The sum of these two parameters is the cyclic length of the schedule. If STGPL2 is assigned 0, there is only one pattern that is repeated. The values for these parameters are given by the TGPL in compressed mode (1...144 WCDMA frames). The distance between two measurement occasions that are assigned for GSM measurements called measurement period (80...640 ms if there are no inter-frequency neighbors and 160...1280 ms if there are inter-fre-

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quency neighbors) and inter RAT measurement periods during the DRX cycle (80 ms to 5.12 s) is calculated by WCDMA physical layer 110 in idle, Cell_PCH and URA_PCH. This gives a range from 0 to 19660800 chip (DRX 5.12 s has to serve as upper limit - twice the length can be achieved if combining STGPL1 and STGPL2).

Schedule Transmission Gap Length 1 and 2 (STGL1 and STGL2) ∈ {0 ... 19660800} [chip] :

[0055] These parameters set the length of the gaps given by the schedule for GSM to measure in. The values for the parameters are given by the transmission gap lengths (TGL) in compressed mode (3, 4, 5, 7, 10 and 14 WCDMA slots), the length of the measurement occasions (1, 2, 4, and 8 WCDMA frames) or the inter RAT measurement periods during the DRX cycle (80 ms to 5.12 s) calculated by WCDMA physical layer 110 in Idle Cell_PCH and URA_PCH. This gives a range from 0 chips to 19660800 chips (DRX 5.12 s serves as upper limit since a complete DRX cycle will never be handed over to GSM). If STGL is assigned 0, a gap does not exist, which may be the case for STGL2.

Schedule Transmission Gap start Distance (STGD) ∈ {0...19660800} [chip] :

[0056] This parameter sets the distance between the starting points for STGL1 and STGL2. The parameter is only valid if STGL2 is greater than 0. The value for this parameter is given in compressed mode by the parameter TGD that is in the range 15...269 WCDMA slots. In measurement occasions and in the inter RAT measurement periods during the DRX cycle maximum STGPL will serve as upper limit, i.e. 19660800 chips. If there is only one gap during the pattern defined by STGPL, then STGD is set to 0.

[0057] The values of the MGS when the WCDMA RAT 100 is in Cell_DCH may be determined as:

SI	TGPSI ∈ {1..6} (Transmission Gap Pattern Sequence Identifier;
SST	$Chip_{CTE\_active\_delta}$+1024 (adjustment for UL-DL time difference);
STGPL1	TGPL1*2560;
STGPL2	TGPL2*2560;
STGL1	TGL1*2560-2048 (adjustment for receiver-transmitter timing difference and UL-DL time difference; adjustment is not necessary in e.g. downlink compressed mode);
STGL2	TGL2*2560-2048 (adjustment for receiver-transmitter timing difference and UL-DL time difference; adjustment is not necessary in e.g. downlink compressed mode); and
STGD	TGD*2560.

[0058] In Cell_FACH the corresponding MGS parameters may be determined as:

SI	1 [no unit] (constant value since only one schedule will be active at the same time in this state);
SST	$Chip_{CTE\_active\_delta}$;
STGPL1	0;
STGPL2	0;
STGL1	N*2560*15;
STGL2	0; and
STGD	0.

[0059] Finally, in idle state the MGS parameters can be determined as:

SI	1 [no unit] (constant value since only one schedule will be active at the same time in this state;
SST	Distance from CTE to first occasion of the MGS schedule;
STGPL1	According to the periods given by the DRX periods
STGPL2	0 (can be used (i.e. not zero) if several gaps need to be defined during one cycle in the schedule);
STGL1	According to planning (based on the DRX periods) performed by the active RAT;
STGL2	0 (can be used (i.e. not zero) if several gaps need to be defined during one cycle in the schedule); and
STGD	0 (can be used (i.e. not zero) if several gaps need to be defined during one cycle in the schedule).

[0060] The CTE which is used to synchronize common time reference of the MGS may be provided by a hardware supported interrupt, i.e. an event caused by an external device which interrupts the ongoing process in the active RAT. The interrupt will call for the counter values to be stored in the counter value registers 157, 257.

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[0061] Fig. 6 illustrates the steps according to one embodiment of the invention for providing the interrupt by issuing the CTE and storing the counter values in response thereto, which provides a common time reference. In a first step 400, it is detected by the controller 130 of the WCDMA physical layer 100 that there is a need for synchronization, i. e. a CTE is needed. An activation request to start a specific measurement pattern from the network may initiate the CTE procedure. Alternatively, the RRC block 120 may (on its own request, e.g. according to instructions which control the operation of said RRC block 120) initiate an activation of the synchronization. The need may be initialized by software run by the controller 130, which will transmit a request for a CTE to the synchronize mechanism 161 of the WCDMA 100. Said synchronize mechanism 161 will then in step 401 issue a synchronization request, which is transmitted to the GSM synchronize mechanism 261. If the GSM access means is run on an internal clock, in a clock evaluation/reconfiguration step 402 a request for an external clock reference will be issued. The external clock reference is necessary if it is required that the timing generator 255 of the GSM RAT 200 have to clock the counter 258 and the counter value register 257 from an external clock to achieve sufficient accuracy and not store erroneous values. An external clock (not shown), such as an voltage controlled oscillator, may serve as the external clock reference, which will clock the counter 258 and register 257 of the GSM RAT 200, and the WCDMA RAT 100 whenever appropriate. Step 402 may be omitted in alternative embodiments of the invention, wherein the external clock reference is not required. In step 403 the CTE is generated by the counter synchronize mechanism 256 of the GSM RAT 200. The CTE is e.g. generated by writing a bit in the HW interface between the GSM RAT 100 and the WCDMA RAT 100. The CTE is in step 404 communicated e.g. over line 300. In step 405 the CTE is received by the counter synchronize mechanism 156 of the WCDMA RAT 100, wherein the CTE interrupt is served in that the counter values are registered. The values are registered approximately simultaneously and stored in the respective counter value registers 157, 257, thus generating the common time reference.

[0062] In an alternative embodiment, the WCDMA timing generator 155 will generate the CTE. If it is not required that either of the RATs 100, 200, are clocked from an external clock reference, it is not necessary to involve the synchronize mechanisms 161, 261. Either of the timing generators 150, 250 may then issue the CTE.

[0063] Step 402 provides the possibility for the GSM RAT to wake up and reconfigure its internal clocks against the external clock reference whenever needed.

[0064] Fig. 7 illustrates the steps carried out according to the invention when interrupts are provided during compressed mode or measurement occasions, i.e. when the WCDMA RAT is in Cell_DCH or Cell_FACH. The MGS is utilized, as the GSM RAT 100 has to plan measurements in advance. Then, the GSM RAT 100 is able to start the correct measurement as soon as the GSM radio is switched on and the WCDMA transceiver 150 is switched off. The synchronization procedure will e.g. start at power on if the WCDMA stack is active. Alternatively, the procedure starts if the active state of the WCDMA RAT 100 is changing or in response to a resynchronization request from the RRC block 120. The start of the procedure will establish measurement synchronization between the GSM and WCDMA RAT 100, 200 and possibly initiate CTE generation. The procedure will be ended when the WCDMA access stack enters into a passive state or into a power off state, or the state is changed.

[0065] The method of Fig. 7 is started in step 500, wherein a measurement configuration request is received by the mobile telephone 1 from the WCDMA telecommunication network 17, to which the WCDMA RAT presently is connected. The configuration request comprises any information necessary to determine the MGS, such as which gaps that may be used by the WCDMA RAT 100 and the GSM RAT 200, respectively. The measurement configuration data, i.e. compressed mode pattern or FACH measurement occasion is stored in step 501, and may be retrieved by the RRC block 120, which will plan the measurements of the WCDMA RAT 100. In step 502 the activation time of the time schedule is determined. The activation time is in Cell_DCH set by the WCDMA telecommunication network 17, whereas the activation time in Cell_FACH is obtained by the WCDMA physical layer 110, e.g. by the CPU 130, based on information received from the UTRAN. In step 503 the transmission gaps, which may be utilized by the GSM RAT 200, are determined. The gaps, which may be utilized by the GSM RAT 200, are in compressed mode given in the measurement configuration data. In Cell_FACH measurement occasions the transmission gaps are divided between the WCDMA RAT 100 and the GSM RAT 200, e.g. according to the 3GPP specification. The CPU 130 determines based on the received information, which gaps should be utilized for WCDMA RAT measurements, such as inter-frequency measurements, and which gaps should be utilized for GSM measurements. In step 504, the parameters of the MGS are obtained. The activation time and the parameters that will be handed over to the GSM RAT 100 are translated into MGS parameters. The parameters of the time schedule are determined based on the common time event CTE, which is issued in response to the activation request of the time schedule prepared in the current step. The MGS parameters including the activation time are forwarded to the GSM RAT in step 505. The GSM RAT 200 receives the MGS parameters in step 506, and translates said parameters into GSM time reference in step 507. In step 508 the planning of the GSM measurements commences, which is also the end of the procedure. The GSM measurements executed by GSM physical layer 210 may now start according to the activation time given in the MGS schedule and is e.g. controlled by the RR block 220 using said schedule.

[0066] Fig. 8 illustrates an alternative embodiment of the steps carried out according to the method of the invention

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when interrupts are provided during DRX measurement cycle, i.e. when the WCDMA RAT is in idle, in Cell_PCH, or URA_PCH state. The procedure is started at power on of the mobile telephone 1 if the WCDMA access stack is active, if any WCDMA active state is changing, or if a resynchronization is requested. The WCDMA physical layer 110 may initiate the synchronization procedure for the MGS method in order to establish synchronization. In a first step 600, the RRC block 120 receives information from the WCDMA network 17 to be able to plan the measurements, such as DRX cycle length and any setup/reconfiguration message. In step 601 the WCDMA physical layer 110 plans for the DRX measurement cycle, i.e. determines which gaps should be utilized for WCDMA RAT and GSM RAT measurements, respectively. A requested activation time is also determined. In step 602 the parameters determined in step 601 are translated into MGS format having reference to a specific CTE. Inter RAT measurement rules, which are known to the WCDMA RAT 100 and which were taken into account when the MGS schedule was obtained, determine when GSM measurements are to commence. In step 603 the RRC block 120 checks whether the GSM RAT 200 shall measure within a predetermined time limit. If so, the MGS schedule is forwarded to the GSM RAT in step 604. Otherwise, the procedure waits in step 603 until a GSM measurement is to commence or the procedure is ended. Alternatively, the time schedule is directly handed over to the GSM RAT 200 as soon as it is obtained. The GSM RAT 200 receives the MGS parameters including a start time for the schedule in step 605. The MGS parameters are translated into GSM reference time in step 606. The RR block 220 may start planning for the GSM measurements in step 607, wherein the WCDMA RAT 100 and the GSM RAT 100 have knowledge of when to execute measurements according to the obtained MGS.

[0067] One difference for the common timing between the idle mode and Cell_DCH or Cell_FACH is that the time references for the different RATs 100, 200 are not locked to each other. This requires that the MGS has to be resynchronized continuously.

[0068] The WCDMA physical layer 110 will start the execution of the measurement patterns, i.e. compressed mode patterns, FACH measurement occasions, or DRX measurement cycle, and may handle the common radio resources, such as the switch 30 and the antenna 10, according to the MGS schedule. The GSM physical layer 210 executes its measurements according to the MGS schedule and will have control over the common radio resources during these measurements when the WCDMA transceiver 150 is temporarily inactive. Alternatively, when separate antennas 10a, 10b are provided no control over the radio resources is necessary, but simultaneous activation (transmission/reception) of the WCDMA RAT 100 and the GSM RAT 200 is avoided by means of the WCDMA and GSM physical layer 110, 210 having knowledge of the MGS schedule.

[0069] The RR block 220 will control the measurements at GSM physical layer 210 using MGS schedule. The measurements are scheduled according to the starting time given by the MGS schedule. In idle state the source of the MGS is DRX measurement. The RRC block 120 will request input information for the MGS schedule from WCDMA physical layer 110, since the WCDMA physical layer 110 is executing the planning of the activities during the cycle to be able to control the measurements.

[0070] The GSM radio transceiver 250 may be active immediately when the WCDMA radio transceiver 150 has been switched off. To ensure that the WCDMA transceiver has been completely switched off before the GSM transceiver 250 is activated a first time margin may be added after the WCDMA transceiver 150 is switched off. Similarly, a second time margin may be added when the GSM transceiver 250 is switched off and the WCDMA transceiver is activated. During the first time margin, the switch 30 may be controlled to switch from the first to the second position. The WCDMA CPU 130 may e.g. control the switching of the switch 30 from the first position, wherein the WCDMA transceiver 150 is connected to the antenna 10, to the second position when the WCDMA transceiver 150 is properly switched off. Similarly, the GSM CPU 230 may control the switch 30 to switch from the second to the first position when the GSM transceiver 250 is properly switched off.

[0071] The WCDMA physical layer 110 is adapted to detect a number of situations wherein the GSM RAT measurements are to be interrupted, which creates a MGS exception. Such exceptions are e.g. during altering state (leaving Cell_FACH), RACH (Random Access CHannel) procedure, BCH (Broadcast CHannel) reading due to paging, SFN (cell System Frame Number), (BCH) reading on neighbors in Cell_FACH and Cell_DCH, compressed mode patterns ends (TGPRC parameter in compressed mode, colliding compressed mode patterns, and state transition, i.e. transition between idle, Cell_PCH, and Cell_FACH). The exceptions are preferably detected by the WCDMA RAT 100, as it is the active RAT requiring the exceptions. In all exceptions, the GSM RAT 100 is notified by an exception interrupt signal, which indicates that GSM measurements should be discontinued, wherein all ongoing measurements are stopped. As soon as the exception is taken care of by the WCDMA RAT 100, the GSM RAT 200 may be informed that GSM measurements may be resumed. In such a case, stored MGS parameters may be utilized for the resumed measurements. The stored parameters may have to be evaluated to secure their validity. The time range for the MGS may have expired, wherein a resynchronization has to be provided. Alternatively, a resynchronization of the RATs 100, 200 is always executed after an exception has been taken care of.

[0072] The MGS procedure according to any of the above embodiments is completely stopped when the WCDMA access stack e.g. enters into a passive state, or is switched off.

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[0073] The present invention has been described above with reference to a mobile telephone. However, the invention may be provided in any portable radio communication equipment, such as a mobile radio terminal, a pager, or a communicator, i.e. an electronic organizer, smartphone or the like having dual RAT capabilities.

[0074] The present invention has been described above with reference to specific embodiments. However, other embodiments than the above described are equally possible within the scope of the invention. Different method steps than those described above, performing the method by hardware or software, may be provided within the scope of the invention. The different features and steps of the invention may be combined in other combinations than those described. The invention is only limited by the appended patent claims

Claims

1. A method for synchronizing measurements in a mobile communication apparatus having a first active radio access means (100) adapted to communicate according to a first radio access technology and a second passive radio access means (200) adapted to communicate according to a second radio access technology, **characterized by:**

   generating a time reference common to the first and the second access means (100, 200);
   obtaining at least one time schedule, said schedule indicating a time gap during which the second access means (200) is allowed to be active; and
   determining an activation time of the time schedule based on the common time reference.

2. The method according to claim 1, wherein, when activation of the time schedule is requested, said request initiates a common time event (CTE), in response to which the time reference is generated in the first and the second access means (100, 200).

3. The method according to claim 2, wherein the CTE is a hardware supported interrupt.

4. The method according to claim 2 or 3, wherein counter values of first and second counters (158, 258) provided in the first and the second access means (100, 200), respectively, are registered in response to the CTE.

5. The method according to claim 4, wherein the current connection frame number, current slot, and current chip are registered by the first access means (100) in response to the CTE.

6. The method according to claim 4 or 5, wherein the current frame number in a GSM multiframe structure, and the position within said frame is registered by the second access means (200) in response to the CTE.

7. The method according to any of the previous claims, wherein the time schedule is obtained based on information received from a first communication network (17) to which the first access means (100) is connected.

8. The method according to claim 7, wherein the received information comprises configuration data specifying gaps, in which the second access means (200) is allowed to be active.

9. The method according to claim 7, wherein the received information comprises setup or reconfiguration information, and the first access means (100) obtains the gaps based on stored and received data.

10. The method according to any of the previous claims, wherein the duration of said gap, and the distance between the common time reference and said gap, are given in the time schedule.

11. The method according to any of the previous claims, wherein several time gaps are determined in the time schedule, and the distance between said gaps is specified in the schedule.

12. The method according to claim 4, wherein a delay between channel timing and the counter (158) of the first access means (100) is taken into account when determining the activation time of the time schedule.

13. The method according to any of the previous claims, wherein the time schedule, which is obtained by the first access means (100), is determined in the time format of a first RAT.

14. The method according to claim 13, wherein the time schedule is translated into the time format of a second RAT

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by the second access means (200).

15. The method according to any of the previous claims, wherein the time schedule is utilized by the second access means (200) to provide cell measurements.

16. An arrangement for synchronizing measurements in a mobile communication apparatus, comprising

a first active radio access means (100) comprising a first transceiver means (150) for communicating with a first communication network (17), said first transceiver means being adapted to communicate according to a first radio access technology;
a second passive radio access means (200) comprising a second transceiver means (250) for communicating with a second communication network (20), said second transceiver means being adapted to communicate according to a second radio access technology;

characterized by:

a time reference generating means (155, 255) for generating a time reference common to the first and the second access means (100, 200);
a time schedule generating means (130) for obtaining at least one time schedule, said schedule indicating at least one time gap, during which the second access means (200) is allowed to be active; and
said time schedule generating means (130) being adapted to determine the activation time of the schedule based on the common time reference.

17. The arrangement according to claim 16, wherein the time reference generating means (155, 255) is adapted to generate a common time event (CTE), and to generate the time reference in response to the CTE in the first and the second access means (100, 200).

18. The arrangement according to claim 17, wherein the time reference generating means (155, 255) comprises first and second counter synchronize mechanisms (156, 157) provided in the first and second access means (100, 200), respectively, one of said mechanisms being adapted to generate an interrupt being the CTE, which the other mechanism is adapted to receive.

19. The arrangement according to claim 18, wherein either or both of the counter synchronize mechanisms (156, 157) are adapted to write a bit onto a connection to the other, said bit being said interrupt.

20. The arrangement according to any of the claims 17 to 19, wherein the time reference generating means comprises first and second counter means (158, 258), and first and second counter value register means (157, 258) provided in the first and second access means (100, 200), respectively.

21. The arrangement according to claim 20, wherein the counter (158) of the first access means (100), in operation, is adapted to generate current connection frame number, current slot, and current chip, which the time reference generating means (155, 255) is adapted to store in the first counter value register means (158) in response to the CTE.

22. The arrangement according to claim 20, wherein the counter (258) of the second access means (200) is adapted to generate the current frame number in GSM multiframe structure, and the position within said frame, which the time reference generating means is adapted to store in the second counter value register means (258) in response to the CTE.

23. The arrangement according to any of the claims 16-22, wherein the time schedule generating means (130) is adapted to obtain the time schedule based on stored information and data received from the first network (17) during operation.

24. The arrangement according to any of the claims 16 to 23, wherein the time schedule generating means (130) is adapted to incorporate into the time schedule parameters that identify the duration of the gap, and the distance between the common time reference and the at least one gap.

25. The arrangement according to any of the claims 16 to 24, wherein the time schedule generating means (130) is

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adapted to incorporate into the time schedule several time gaps, and to specify the distance between said gaps in the schedule.

26. The arrangement according to any of the claims 16 to 25, wherein the time schedule generating means (130) is adapted to in operation determine the time schedule in the time format of the first access technology.

27. The arrangement according to claim 26, wherein a processor means (230) of the second access means (200) is adapted to in operation translate the time schedule into the time format of the second access technology.

28. The arrangement according to any of the claims 16 to 27, wherein the second access means (200) is adapted to provide cell measurements during the gaps given in the time schedule, and wherein the first access means (100) is adapted to be passive.

29. The arrangement according to any of the claims 16 to 28, wherein the first radio access technology is WCDMA (Wideband Code Division Multiple Access).

30. The arrangement according to any of the claims 16 to 29, wherein the second access technology is GSM (Global System for Mobile communication).

31. The arrangement according to any of the claims 16 to 30, wherein said first and second access means (100, 200) have at least one common radio resource (10, 30).

32. The arrangement according to claim 31, wherein the common radio resource is an antenna (10).

33. A computer program product directly loadable into a memory (153, 253) of a mobile terminal (1) having digital computer capabilities, comprising software code portions for performing the steps of claim 1 when said product is run by said mobile terminal (1).

34. Use of an arrangement according to any of the claims 16 to 32 in a wireless communication apparatus (1).

35. The use of the arrangement according to claim 34, wherein the apparatus is a mobile radio terminal, a mobile telephone (1), a pager or a communicator.

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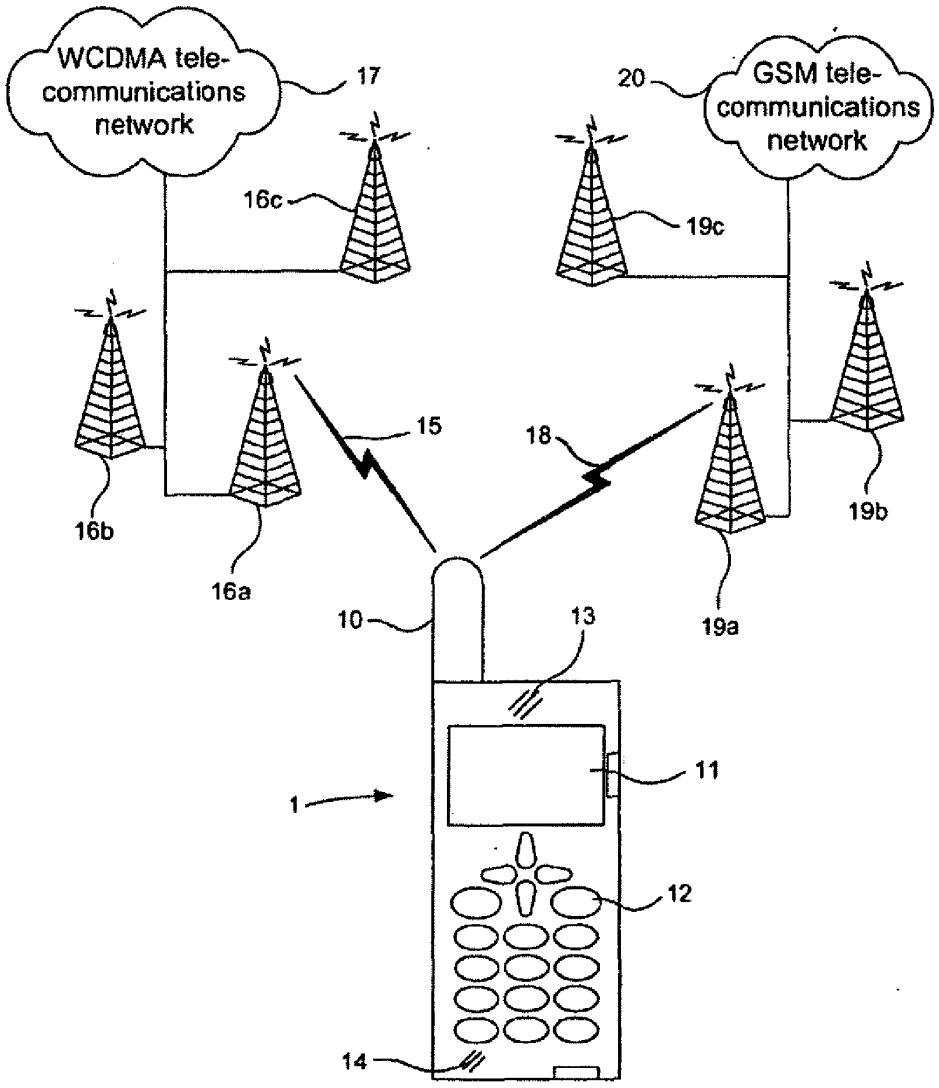

WCDMA tele-communications network
17
20
GSM tele-communications network
16c
19c
15
18
16b
19b
16a
19a
10
13
11
1
12
14

Fig. 1

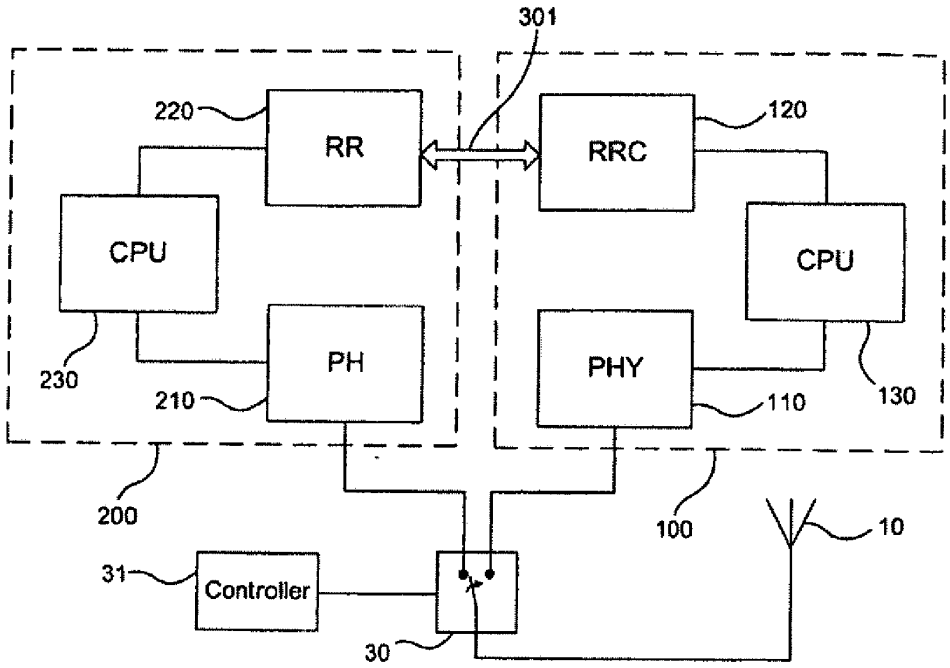

301
220
RR
RRC
120
CPU
CPU
230
PH
PHY
210
110
130
200
100
10
31
Controller
30

Fig. 2a

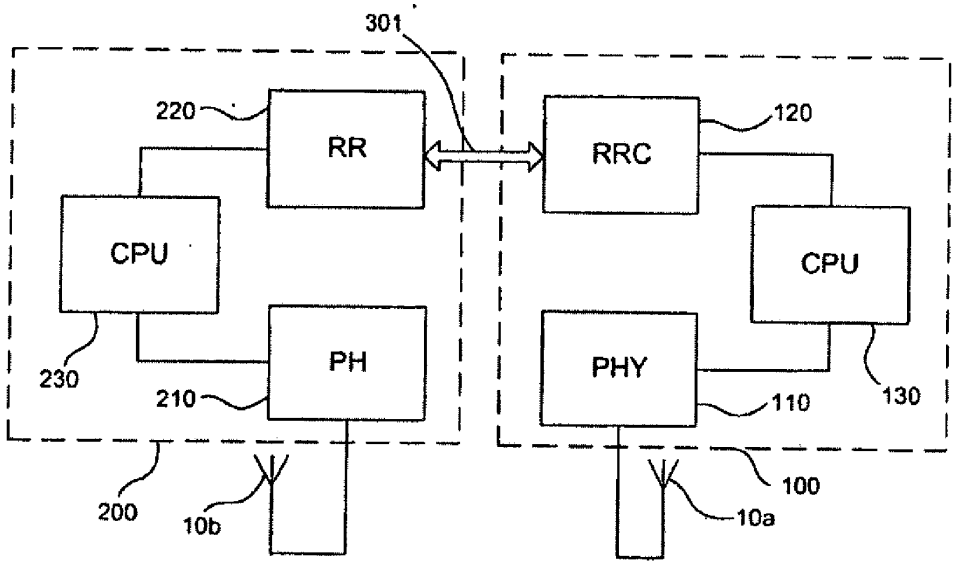

301
220
RR
RRC
120
CPU
CPU
230
PH
PHY
210
110
130
100
200
10b
10a

Fig. 2b

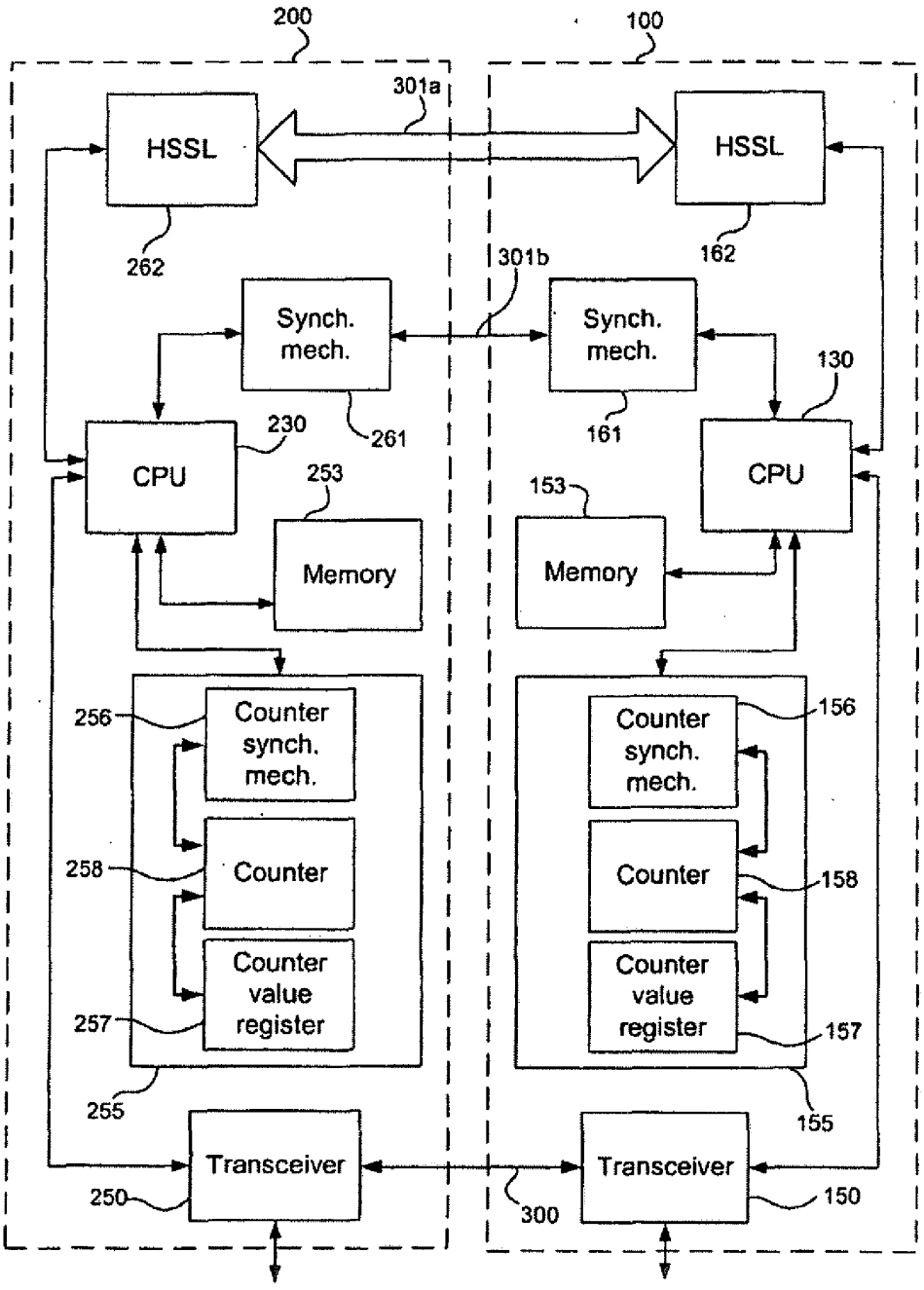

200
100
301a
HSSL
HSSL
262
162
301b
Synch. mech.
Synch. mech.
130
230
261
161
CPU
CPU
253
153
Memory
Memory
256
Counter synch. mech.
156
Counter synch. mech.
258
Counter
Counter
158
Counter value register
Counter value register
257
157
255
155
Transceiver
Transceiver
250
300
150

Fig. 3

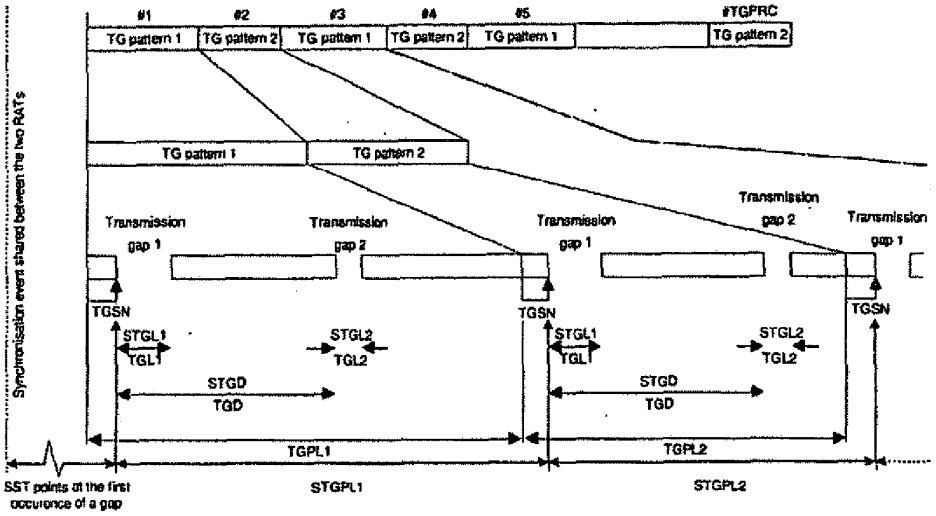

#1
#2
#3
#4
#5
#TGPRC
TG pattern 1
TG pattern 2
TG pattern 1
TG pattern 2
TG pattern 1
TG pattern 2
TG pattern 1
TG pattern 2
Synchronisation event shared between the two RATs
Transmission gap 1
Transmission gap 2
Transmission gap 1
Transmission gap 2
Transmission gap 1
TGSN
TGSN
TGSN
STGL1
TGL1
STGL2
TGL2
STGL1
TGL1
STGL2
TGL2
STGD
TGD
STGD
TGD
TGPL1
TGPL2
SST points at the first occurence of a gap
STGPL1
STGPL2

Fig. 4

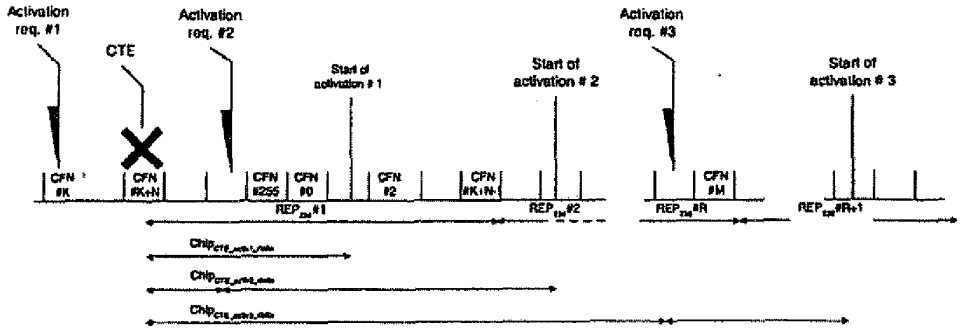

Activation req. #1
CTE
Activation req. #2
Start of activation # 1
Start of activation # 2
Activation req. #3
Start of activation # 3
CFN #K
CFN #K+N
CFN #255
CFN #0
CFN #2
CFN #K+N
CFN #M
REP#1
REP#2
REP#R
REP#R+1

Fig. 5

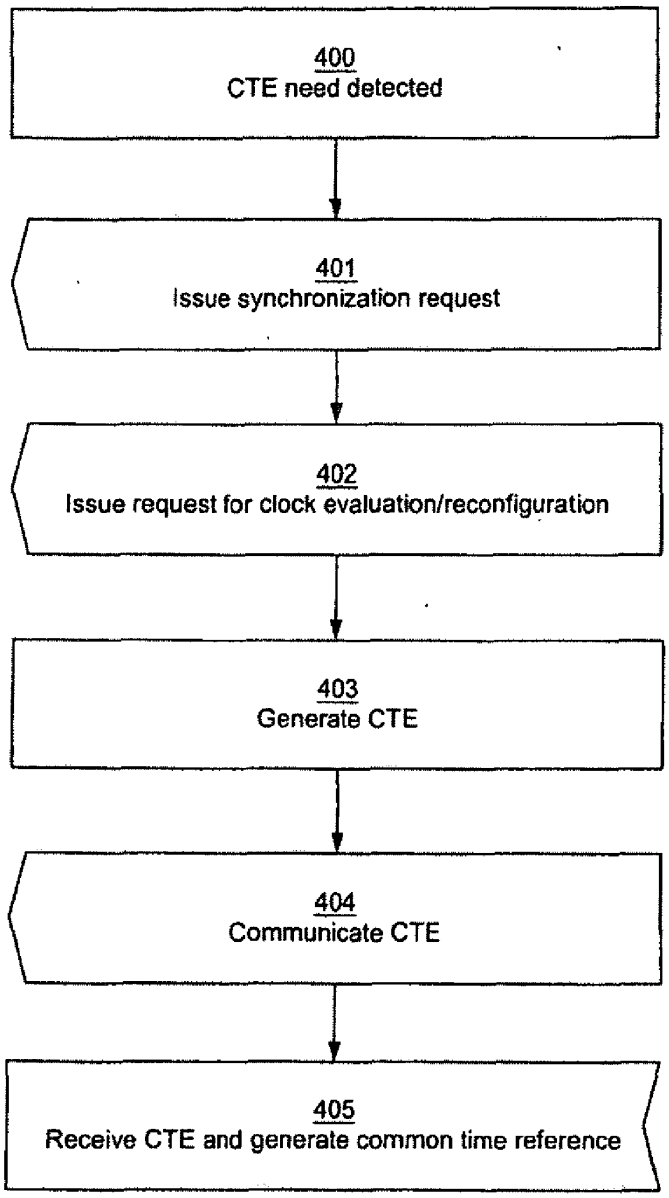

400
CTE need detected
401
Issue synchronization request
402
Issue request for clock evaluation/reconfiguration
403
Generate CTE
404
Communicate CTE
405
Receive CTE and generate common time reference

Fig. 6

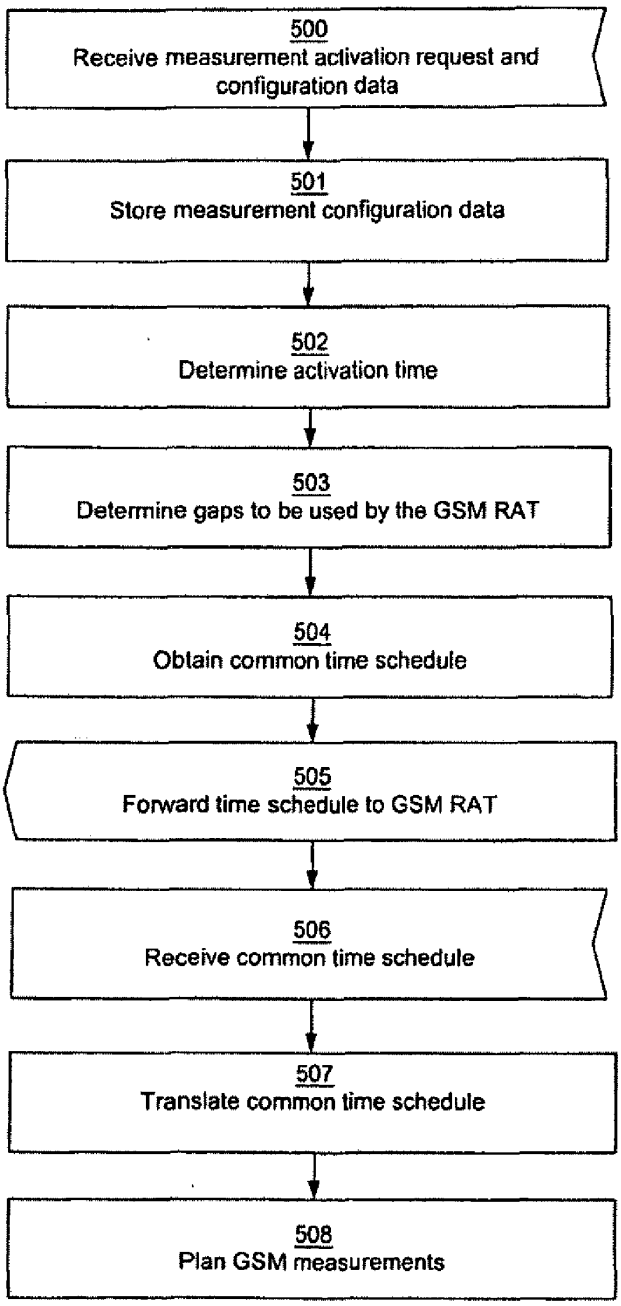


Fig. 7

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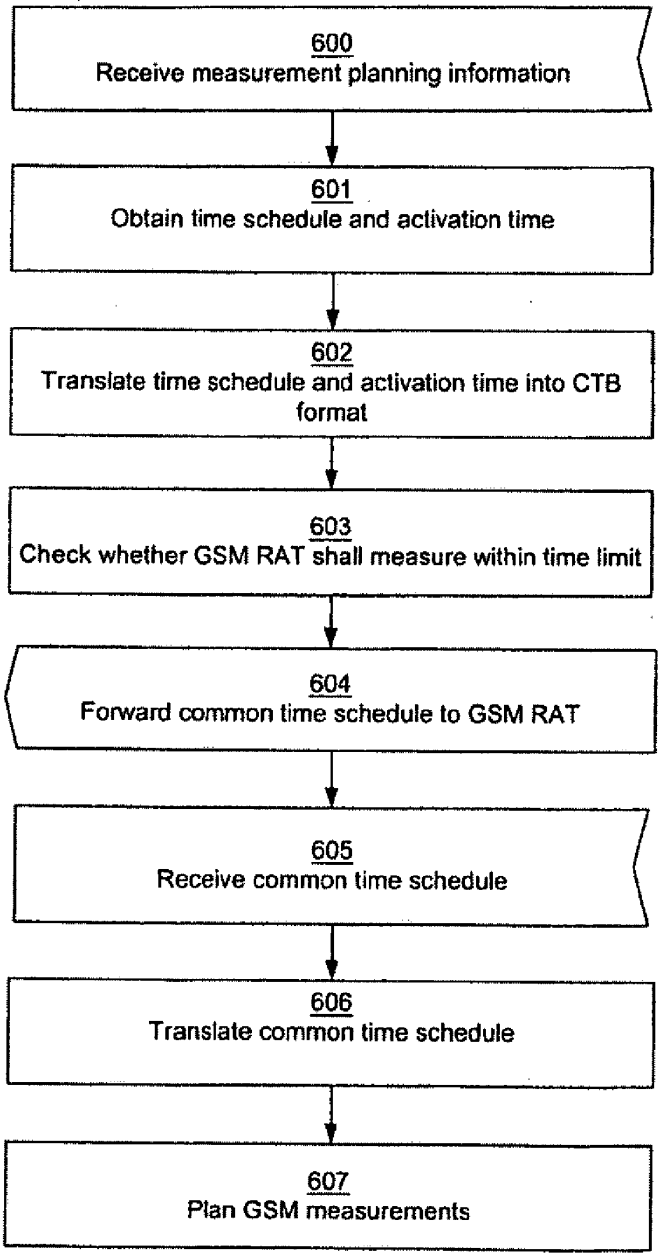


Fig. 8

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 00 8440

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	WO 02 39758 A (SCHNIEDENHARN JOERG ;BREUER VOLKER (DE); SIEMENS AG (DE); WEGNER F) 16 May 2002 (2002-05-16) * abstract * * page 1, line 34 - page 5, line 14 * * page 6, line 14 - page 8, line 22 * * page 10, line 5-18 * * claims *	1-35	H04Q7/32 H04Q7/38
A	EP 1 030 477 A (NOKIA MOBILE PHONES LTD) 23 August 2000 (2000-08-23) * abstract * * column 1, line 3-12 * * column 3, line 23 - column 4, line 57 * * column 6, line 6 - column 7, line 26 * * column 9, line 13 - column 10, line 26 * * claims *	1-35	
A	US 2003/003951 A1 (LEPRIEUR PHILIPPE ET AL) 2 January 2003 (2003-01-02) * the whole document *	1-35	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H04Q
H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15 August 2003	Dejonghe, O

CATEGORY OF CITED DOCUMENTS
X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 00 8440

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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15-08-2003

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WO 0239758 A	16-05-2002	AU 2155902 A	21-05-2002
		WO 0239758 A2	16-05-2002
		EP 1334632 A2	13-08-2003
EP 1030477 A	23-08-2000	FI 990361 A	20-08-2000
		EP 1030477 A2	23-08-2000
		JP 2000252968 A	14-09-2000
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		CN 1400835 A	05-03-2003
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		JP 2003032756 A	31-01-2003

EPO FORM P1/55

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 615 384 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
11.01.2006 Bulletin 2006/02

(51) Int Cl.:
H04L 12/28 *(2006.01)*

(21) Application number: **05019630.2**

(22) Date of filing: **24.10.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(30) Priority: **25.10.2002 US 421309 P**
23.10.2003 US 693419

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
03781524.8 / 1 582 032

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Remarks:
This application was filed on 09 - 09 - 2005 as a divisional application to the application mentioned under INID code 62.

(54) Mimo wlan system

(57) A method and apparatus in a multiple-access MIMO WLAN system that employs MIMO, OFDM, and TDD for processing data for transmission. The data is processed by coding a data frame in accordance with a coding scheme to obtain a coded data frame, partitioning the coded data frame into a plurality of coded data subframes, one coded data subframe for each of a plurality of spatial channels, and interleaving each coded data subframe in accordance with an interleaving scheme to obtain a corresponding interleaved data subframe, where a plurality of interleaved data subframes are obtained for the plurality of spatial channels. Each interleaved data subframe is modulated to obtain a corresponding stream of modulation symbols, where a plurality of modulation symbol streams are obtained for the plurality of spatial channels.

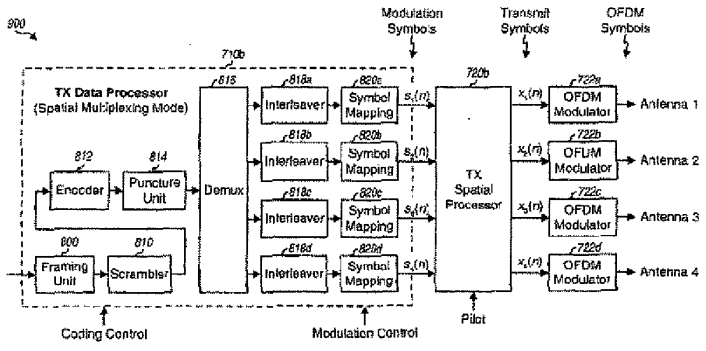


FIG. 9A

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Printed by Jouve, 75001 PARIS (FR)

Description

Claim of Priority under 35 U.S.C. §119

[0001] This application claims the benefit of provisional U.S. Application Serial No. 60/421,309, entitled, "MIMO WLAN System," filed on October 25, 2002.

BACKGROUND

Field

[0002] The present invention relates generally to data communication, and more specifically to a multiple-input multiple-output (MIMO) wireless local area network (WLAN) communication system.

Background

[0003] Wireless communication systems are widely deployed to provide various types of communication such as voice, packet data, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users sequentially or simultaneously by sharing the available system resources. Examples of multiple-access systems include Code Division Multiple Access (CDMA) systems, Time Division Multiple Access (TDMA) systems, and Frequency Division Multiple Access (FDMA) systems.

[0004] Wireless local area networks (WLANs) are also widely deployed to enable communication among wireless electronic devices (e.g., computers) via wireless link. A WLAN may employ access points (or base stations) that act like hubs and provide connectivity for the wireless devices. The access points may also connect (or "bridge") the WLAN to wired LANs, thus allowing the wireless devices access to LAN resources.

[0005] In a wireless communication system, a radio frequency (RF) modulated signal from a transmitter unit may reach a receiver unit via a number of propagation paths. The characteristics of the propagation paths typically vary over time due to a number of factors, such as fading and multipath. To provide diversity against deleterious path effects and improve performance, multiple transmit and receive antennas may be used. If the propagation paths between the transmit and receive antennas are linearly independent (i.e., a transmission on one path is not formed as a linear combination of the transmissions on the other paths), which is generally true to at least an extent, then the likelihood of correctly receiving a data transmission increases as the number of antennas increases. Generally, diversity increases and performance improves as the number of transmit and receive antennas increases.

[0006] A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S spatial channels, with $N_S \leq \min\{N_T, N_R\}$. Each of the N_S spatial channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., increased transmission capacity and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0007] The resources for a given communication system are typically limited by various regulatory constraints and requirements and by other practical considerations. However, the system may be required to support a number of terminals, provide various services, achieve certain performance goals, and so on.

[0008] There is, therefore, a need in the art for a MIMO WLAN system capable of supporting multiple users and providing high system performance.

SUMMARY

[0009] A multiple-access MIMO WLAN system having various capabilities and able to achieve high performance is described herein. In an embodiment, the system employs MIMO and orthogonal frequency division multiplexing (OFDM) to attain high throughput, combat deleterious path effects, and provide other benefits. Each access point in the system can support multiple user terminals. The allocation of downlink and uplink resources is dependent on the requirements of the user terminals, the channel conditions, and other factors.

[0010] A channel structure supporting efficient downlink and uplink transmissions is also provided herein. The channel structure comprises a number of transport channels that may be used for a number of functions, such as signaling of system parameters and resource assignments, downlink and uplink data transmissions, random access of the system, and so on. Various attributes of these transport channels are configurable, which allows the system to easily adapt to changing channel and loading conditions.

[0011] Multiple rates and transmission modes are supported by the MIMO WLAN system to attain high throughput when supported by the channel conditions and the capabilities of the user terminals. The rates are configurable based

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on estimates of the channel conditions and may be independently selected for the downlink and uplink. Different transmission modes may also be used, depending on the number of antennas at the user terminals and the channel conditions. Each transmission mode is associated with different spatial processing at the transmitter and receiver and may be selected for use under different operating conditions. The spatial processing facilitates data transmission from multiple transmit antennas and/or data reception with multiple receive antennas for higher throughput and/or diversity.

[0012] In an embodiment, the MIMO WLAN system uses a single frequency band for both the downlink and uplink, which share the same operating band using time division duplexing (TDD). For a TDD system, the downlink and uplink channel responses are reciprocal. Calibration techniques are provided herein to determine and account for differences in the frequency responses of the transmit/receive chains at the access point and user terminals. Techniques are also described herein to simplify the spatial processing at the access point and user terminals by taking advantage of the reciprocal nature of the downlink and uplink and the calibration.

[0013] A pilot structure with several types of pilot used for different functions is also provided. For example, a beacon pilot may be used for frequency and system acquisition, a MIMO pilot may be used for channel estimation, a steered reference (i.e., a steered pilot) may be used for improved channel estimation, and a carrier pilot may be used for phase tracking.

[0014] Various control loops for proper system operation are also provided. Rate control may be exercised independently on the downlink and uplink. Power control may be exercised for certain transmissions (e.g., fixed-rate services). Timing control may be used for uplink transmissions to account for different propagation delays of user terminals located throughout the system.

[0015] Random access techniques to allow user terminals to access the system are also provided. These techniques support system access by multiple user terminals, fast acknowledgment of system access attempts, and quick assignment of downlink/uplink resources.

[0016] The various aspects and embodiments of the invention are described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The features and nature of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[0018] FIG. 1 shows a MIMO WLAN system;

[0019] FIG. 2 shows a layer structure for the MIMO WLAN system;

[0020] FIGS. 3A, 3B and 3C show a TDD-TDM frame structure, an FDD-TDM frame structure, and an FDD-CDM frame structure, respectively;

[0021] FIG. 4 shows the TDD-TDM frame structure with five transport channels - BCH, FCCH, FCH, RCH, and RACH;

[0022] FIGS. 5A through 5G show various protocol data unit (PDU) formats for the five transport channels;

[0023] FIG. 6 shows a structure for an FCH/RCH packet;

[0024] FIG. 7 shows an access point and two user terminals;

[0025] FIGS. 8A, 9A, and 10A show three transmitter units for the diversity, spatial multiplexing, and beam-steering modes, respectively;

[0026] FIGS. 8B, 9B, and 10B show three TX diversity processors for the diversity, spatial multiplexing, and beam-steering modes, respectively,

[0027] FIG. 8C shows an OFDM modulator;

[0028] FIG. 8D shows an OFDM symbol;

[0029] FIG. 11A shows a framing unit and a scrambler within a TX data processor;

[0030] FIG. 11B shows an encoder and a repeat/puncture unit within the TX data processor;

[0031] FIG. 11C shows another TX data processor that may be used for the spatial multiplexing mode;

[0032] FIGS. 12A and 12B show a state diagram for operation of a user terminal;

[0033] FIG. 13 shows a timeline for the RACH;

[0034] FIGS. 14A and 14B show processes for controlling the rates of downlink and uplink transmissions, respectively;

[0035] FIG. 15 shows the operation of a power control loop; and

[0036] FIG. 16 shows a process for adjusting the uplink timing of a user terminal.

DETAILED DESCRIPTION

[0037] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs.

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I. Overall System

[0038] **FIG. 1** shows a MIMO WLAN system 100 that supports a number of users and is capable of implementing various aspects and embodiments of the invention. MIMO WLAN system 100 includes a number of access points (APs) 110 that support communication for a number of user terminals (UTs) 120. For simplicity, only two access points 110 are shown in FIG. 1. An access point is generally a fixed station that is used for communicating with the user terminals. An access point may also be referred to as a base station or some other terminology.

[0039] User terminals 120 may be dispersed throughout the system. Each user terminal may be a fixed or mobile terminal that can communicate with the access point. A user terminal may also be referred to as a mobile station, a remote station, an access terminal, a user equipment (UE), a wireless device, or some other terminology. Each user terminal may communicate with one or possibly multiple access points on the downlink and/or uplink at any given moment. The downlink (i.e., forward link) refers to transmission from the access point to the user terminal, and the uplink (i.e., reverse link) refers to transmission from the user terminal to the access point.

[0040] In FIG. 1, access point 110a communicates with user terminals 120a through 120f, and access point 110b communicates with user terminals 120f through 120k. Depending on the specific design of system 100, an access point may communicate with multiple user terminals simultaneously (e.g., via multiple code channels or subbands) or sequentially (e.g., via multiple time slots). At any given moment, a user terminal may receive downlink transmissions from one or multiple access points. The downlink transmission from each access point may include overhead data intended to be received by multiple user terminals, user-specific data intended to be received by specific user terminals, other types of data, or any combination thereof. The overhead data may include pilot, page and broadcast messages, system parameters, and so on.

[0041] The MIMO WLAN system is based on a centralized controller network architecture. Thus, a system controller 130 couples to access points 110 and may further couple to other systems and networks. For example, system controller 130 may couple to a packet data network (PDN), a wired local area network (LAN), a wide area network (WAN), the Internet, a public switched telephone network (PSTN), a cellular communication network, and so on. System controller 130 may be designed to perform a number of functions such as (1) coordination and control for the access points coupled to it, (2) routing of data among these access points, (3) access and control of communication with the user terminals served by these access points, and so on.

[0042] The MIMO WLAN system may be able to provide high throughput with significantly greater coverage capability than conventional WLAN systems. The MIMO WLAN system can support synchronous, asynchronous, and isochronous data/voice services. The MIMO WLAN system may be designed to provide the following features:

- High service reliability
- Guaranteed quality of service (QoS)
- High instantaneous data rates
- High spectral efficiency
- Extended coverage range.

[0043] The MIMO WLAN system may be operated in various frequency bands (e.g., the 2.4 GHz and 5.x GHz U-NII bands), subject to the bandwidth and emission constraints specific to the selected operating band. The system is designed to support both indoor and outdoor deployments, with typical maximum cell size of 1 km or less. The system supports fixed terminal applications, although some operating modes also support portable and limited mobility operation.

1. MIMO, MISO, and SIMO

[0044] In a specific embodiment and as described throughout the specification, each access point is equipped with four transmit and receive antennas for data transmission and reception, where the same four antennas are used to transmit and to receive. The system also supports the case where the transmit and receive antennas of the device (e.g. access point, user terminal) are not shared, even though this configuration normally provides lower performance than when the antennas are shared. The MIMO WLAN system may also be designed such that each access point is equipped with some other number of transmit/receive antennas. Each user terminal may be equipped with a single transmit/receive antenna or multiple transmit/receive antennas for data transmission and reception. The number of antennas employed by each user terminal type may be dependent on various factors such as, for example, the services to be supported by the user terminal (e.g., voice, data, or both), cost considerations, regulatory constraints, safety issues, and so on.

[0045] For a given pairing of multi-antenna access point and multi-antenna user terminal, a MIMO channel is formed by the N_T transmit antennas and N_R receive antennas available for use for data transmission. Different MIMO channels are formed between the access point and different multi-antenna user terminals. Each MIMO channel may be decomposed into N_S spatial channels, with $N_S \leq \min\{N_T, N_R\}$. N_S data streams may be transmitted on the N_S spatial channels.

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Spatial processing is required at a receiver and may or may not be performed at a transmitter in order to transmit multiple data streams on the N_S spatial channels.

[0046] The N_S spatial channels may or may not be orthogonal to one another. This depends on various factors such as (1) whether or not spatial processing was performed at the transmitter to obtain orthogonal spatial channels and (2) whether or not the spatial processing at both the transmitter and the receiver was successful in orthogonalizing the spatial channels. If no spatial processing is performed at the transmitter, then the N_S spatial channels may be formed with N_S transmit antennas and are unlikely to be orthogonal to one another.

[0047] The N_S spatial channels may be orthogonalized by performing decomposition on a channel response matrix for the MIMO channel, as described below. Each spatial channel is referred to as an eigenmode of the MIMO channel if the N_S spatial channels are orthogonalized using decomposition, which requires spatial processing at both the transmitter and the receiver, as described below. In this case, N_S data streams may be transmitted orthogonally on the N_S eigenmodes. However, an eigenmode normally refers to a theoretical construct. The N_S spatial channels are typically not completely orthogonal to one another due to various reasons. For example, the spatial channels would not be orthogonal if (1) the transmitter has no knowledge of the MIMO channel or (2) the transmitter and/or receiver have imperfect estimate of the MIMO channel. For simplicity, in the following description, the term "eigenmode" is used to denote the case where an attempt is made to orthogonalize the spatial channels using decomposition, even though the attempt may not be fully successful due to, for example, an imperfect channel estimate.

[0048] For a given number of (e.g., four) antennas at the access point, the number of spatial channels available for each user terminal is dependent on the number of antennas employed by that user terminal and the characteristics of the wireless MIMO channel that couples the access point antennas and the user terminal antennas. If a user terminal is equipped with one antenna, then the four antennas at the access point and the single antenna at the user terminal form a multiple-input single-output (MISO) channel for the downlink and a single-input multiple-output (SIMO) channel for the uplink.

[0049] The MIMO WLAN system may be designed to support a number of transmission modes. Table 1 lists the transmission modes supported by an exemplary design of the MIMO WLAN system.

Table 1

Transmission modes	Description
SIMO	Data is transmitted from a single antenna but may be received by multiple antennas for receive diversity.
Diversity	Data is redundantly transmitted from multiple transmit antennas and/or multiple subbands to provide diversity.
Beam-steering	Data is transmitted on a single (best) spatial channel at full power using phase steering information for the principal eigenmode of the MIMO channel.
Spatial multiplexing	Data is transmitted on multiple spatial channels to achieve higher spectral efficiency.

For simplicity, the term "diversity" refers to transmit diversity in the following description, unless noted otherwise.

[0050] The transmission modes available for use for the downlink and uplink for each user terminal are dependent on the number of antennas employed at the user terminal. Table 2 lists the transmission modes available for different terminal types for the downlink and uplink, assuming multiple (e.g., four) antennas at the access point.

Table 2

Transmission modes	Downlink		Uplink	
	Single-antenna user terminal	Multi-antenna user terminal	Single-antenna user terminal	Multi-antenna user terminal
MISO (on downlink)/ SIMO (on uplink)	X	X	X	X
Diversity	X	X		X
Beam-steering	X	X		X
Spatial multiplexing		X		X

For the downlink, all of the transmission modes except for the spatial multiplexing mode may be used for single-antenna

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user terminals, and all transmission modes may be used for multi-antenna user terminals. For the uplink, all transmission modes may be used by multi-antenna user terminals, while single-antenna user terminals use the SIMO mode to transmit data from the one available antenna. Receive diversity (i.e., receiving a data transmission with multiple receive antennas) may be used for the SIMO, diversity, and beam-steering modes.

[0051] The MIMO WLAN system may also be designed to support various other transmission modes, and this is within the scope of the invention. For example, a beam-forming mode may be used to transmit data on a single eigenmode using both the amplitude and phase information for the eigenmode (instead of only the phase information, which is all that is used by the beam-steering mode). As another example, a "non-steered" spatial multiplexing mode can be defined whereby the transmitter simply transmits multiple data streams from multiple transmit antennas (without any spatial processing) and the receiver performs the necessary spatial processing to isolate and recover the data streams sent from the multiple transmit antennas. As yet another example, a "multi-user" spatial multiplexing mode can be defined whereby the access point transmits multiple data streams from multiple transmit antennas (with spatial processing) to multiple user terminals concurrently on the downlink. As yet another example, a spatial multiplexing mode can be defined whereby the transmitter performs spatial processing to attempt to orthogonalize the multiple data streams sent on the multiple transmit antennas (but may not be completely successful because of an imperfect channel estimate) and the receiver performs the necessary spatial processing to isolate and recover the data streams sent from the multiple transmit antennas. Thus, the spatial processing to transmit multiple data streams via multiple spatial channels may be performed (1) at both the transmitter and receiver, (2) at only the receiver, or (3) at only the transmitter. Different spatial multiplexing modes may be used depending on, for example, the capabilities of the access point and the user terminals, the available channel state information, system requirements, and so on.

[0052] In general, the access points and user terminals may be designed with any number of transmit and receive antennas. For clarity, specific embodiments and designs are described below whereby each access point is equipped with four transmit/receive antennas, and each user terminal is equipped with four or less transmit/receive antennas.

2. OFDM

[0053] In an embodiment, the MIMO WLAN system employs OFDM to effectively partition the overall system bandwidth into a number of (N_F) orthogonal subbands. These subbands are also referred to as tones, bins, or frequency channels. With OFDM, each subband is associated with a respective subcarrier that may be modulated with data. For a MIMO system that utilizes OFDM, each spatial channel of each subband may be viewed as an independent transmission channel where the complex gain associated with each subband is effectively constant across the subband bandwidth.

[0054] In an embodiment, the system bandwidth is partitioned into 64 orthogonal subbands (i.e., $N_F = 64$), which are assigned indices of -32 to +31. Of these 64 subbands, 48 subbands (e.g., with indices of $\pm\{1, ..., 6, 8, ..., 20, 22, ..., 26\}$) are used for data, 4 subbands (e.g., with indices of $\pm\{7, 21\}$) are used for pilot and possibly signaling, the DC subband (with index of 0) is not used, and the remaining subbands are also not used and serve as guard subbands. This OFDM subband structure is described in further detail in a document for IEEE Standard 802.11a and entitled "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: High-speed Physical Layer in the 5 GHz Band," September 1999, which is publicly available and incorporated herein by reference. Different numbers of subbands and various other OFDM subband structures may also be implemented for the MIMO WLAN system, and this is within the scope of the invention. For example, all 53 subbands with indices from -26 to +26 may be used for data transmission. As another example, a 128-subband structure, a 256-subband structure, or a subband structure with some other number of subbands may be used. For clarity, the MIMO WLAN system is described below with the 64-subband structure described above.

[0055] For OFDM, the data to be transmitted on each subband is first modulated (i.e., symbol mapped) using a particular modulation scheme selected for use for that subband. Zeros are provided for the unused subbands. For each symbol period, the modulation symbols and zeros for all N_F subbands are transformed to the time domain using an inverse fast Fourier transform (IFFT) to obtain a transformed symbol that contains N_F time-domain samples. The duration of each transformed symbol is inversely related to the bandwidth of each subband. In one specific design for the MIMO WLAN system, the system bandwidth is 20 MHz, $N_F = 64$, the bandwidth of each subband is 312.5 KHz, and the duration of each transformed symbol is 3.2 μsec.

[0056] OFDM can provide certain advantages, such as the ability to combat frequency selective fading, which is characterized by different channel gains at different frequencies of the overall system bandwidth. It is well known that frequency selective fading causes inter-symbol interference (ISI), which is a phenomenon whereby each symbol in a received signal acts as distortion to subsequent symbols in the received signal. The ISI distortion degrades performance by impacting the ability to correctly detect the received symbols. Frequency selective fading can be conveniently combated with OFDM by repeating a portion of (or appending a cyclic prefix to) each transformed symbol to form a corresponding OFDM symbol, which is then transmitted.

[0057] The length of the cyclic prefix (i.e., the amount to repeat) for each OFDM symbol is dependent on the delay

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spread of the wireless channel. In particular, to effectively combat ISI, the cyclic prefix should be longer than the maximum expected delay spread for the system.

[0058] In an embodiment, cyclic prefixes of different lengths may be used for the OFDM symbols, depending on the expected delay spread. For the specific MIMO WLAN system described above, a cyclic prefix of 400 nsec (8 samples) or 800 nsec (16 samples) may be selected for use for the OFDM symbols. A "short" OFDM symbol uses the 400 nsec cyclic prefix and has a duration of 3.6 μsec. A "long" OFDM symbol uses the 800 nsec cyclic prefix and has a duration of 4.0 μsec. Short OFDM symbols may be used if the maximum expected delay spread is 400 nsec or less, and long OFDM symbols may be used if the delay spread is greater than 400 nsec. Different cyclic prefixes may be selected for use for different transport channels, and the cyclic prefix may also be dynamically selectable, as described below. Higher system throughput may be achieved by using the shorter cyclic prefix when possible, since more OFDM symbols of shorter duration can be transmitted over a given fixed time interval.

[0059] The MIMO WLAN system may also be designed to not utilize OFDM, and this is within the scope of the invention.

3. Layer Structure

[0060] FIG. 2 illustrates a layer structure 200 that may be used for the MIMO WLAN system. Layer structure 200 includes (1) applications and upper layer protocols that approximately correspond to Layer 3 and higher of the ISO/OSI reference model (upper layers), (2) protocols and services that correspond to Layer 2 (the link layer), and (3) protocols and services that correspond to Layer 1 (the physical layer).

[0061] The upper layers includes various applications and protocols, such as signaling services 212, data services 214, voice services 216, circuit data applications, and so on. Signaling is typically provided as messages and data is typically provided as packets. The services and applications in the upper layers originate and terminate messages and packets according to the semantics and timing of the communication protocol between the access point and the user terminal. The upper layers utilize the services provided by Layer 2.

[0062] Layer 2 supports the delivery of messages and packets generated by the upper layers. In the embodiment shown in FIG. 2, Layer 2 includes a Link Access Control (LAC) sublayer 220 and a Medium Access Control (MAC) sublayer 230. The LAC sublayer implements a data link protocol that provides for the correct transport and delivery of messages generated by the upper layers. The LAC sublayer utilizes the services provided by the MAC sublayer and Layer 1. The MAC sublayer is responsible for transporting messages and packets using the services provided by Layer 1. The MAC sublayer controls the access to Layer 1 resources by the applications and services in the upper layers. The MAC sublayer may include a Radio Link Protocol (RLP) 232, which is a retransmission mechanism that may be used to provide higher reliability for packet data. Layer 2 provides protocol data units (PDUs) to Layer 1.

[0063] Layer 1 comprises physical layer 240 and supports the transmission and reception of radio signals between the access point and user terminal. The physical layer performs coding, interleaving, modulation, and spatial processing for various transport channels used to send messages and packets generated by the upper layers. In this embodiment, the physical layer includes a multiplexing sublayer 242 that multiplexes processed PDUs for various transport channels into the proper frame format. Layer 1 provides data in units of frames.

[0064] FIG. 2 shows a specific embodiment of a layer structure that may be used for the MIMO WLAN system. Various other suitable layer structures may also be designed and used for the MIMO WLAN system, and this is within the scope of the invention. The functions performed by each layer are described in further detail below where appropriate.

4. Transport Channels

[0065] A number of services and applications may be supported by the MIMO WLAN system. Moreover, other data required for proper system operation may need to be sent by the access point or exchanged between the access point and user terminals. A number of transport channels may be defined for the MIMO WLAN system to carry various types of data. Table 3 lists an exemplary set of transport channels and also provides a brief description for each transport channel.

Table 3

Transport channels		Description
Broadcast channel	BCH	Used by the access point to transmit pilot and system parameters to the user terminals.
Forward control channel	FCCH	Used by the access point to allocate resources on the downlink and uplink. The resource allocation may be performed on a frame-by-frame basis. Also used to provide acknowledgment for messages received on the RACH.

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Table continued

Transport channels		Description
Forward channel	FCH	Used by the access point to transmit user-specific data to the user terminals and possibly a reference (pilot) used by the user terminals for channel estimation. May also be used in a broadcast mode to send page and broadcast messages to multiple user terminals.
Random access channel	RACH	Used by the user terminals to gain access to the system and send short messages to the access point.
Reverse channel	RCH	Used by the user terminals to transmit data to the access point. May also carry a reference used by the access point for channel estimation.

[0066] As shown in Table 3, the downlink transport channels used by the access point includes the BCH, FCCH, and FCH. The uplink transport channels used by the user terminals include the RACH and RCH. Each of these transport channels is described in further detail below.

[0067] The transport channels listed in Table 3 represent a specific embodiment of a channel structure that may be used for the MIMO WLAN system. Fewer, additional, and/or different transport channels may also be defined for use for the MIMO WLAN system. For example, certain functions may be supported by function-specific transport channels (e.g., pilot, paging, power control, and sync channel channels). Thus, other channel structures with different sets of transport channels may be defined and used for the MIMO WLAN system, and this is within the scope of the invention.

5. Frame Structures

[0068] A number of frame structures may be defined for the transport channels. The specific frame structure to use for the MIMO WLAN system is dependent on various factors such as, for example, (1) whether the same or different frequency bands are used for the downlink and uplink and (2) the multiplexing scheme used to multiplex the transport channels together.

[0069] If only one frequency band is available, then the downlink and uplink may be transmitted on different phases of a frame using time division duplexing (TDD), as described below. If two frequency bands are available, then the downlink and uplink may be transmitted on different frequency bands using frequency division duplexing (FDD).

[0070] For both TDD and FDD, the transport channels may be multiplexed together using time division multiplexing (TDM), code division multiplexing (CDM), frequency division multiplexing (FDM), and so on. For TDM, each transport channel is assigned to a different portion of a frame. For CDM, the transport channels are transmitted concurrently but each transport channel is channelized by a different channelization code, similar to that performed in a code division multiple access (CDMA) system. For FDM, each transport channel is assigned a different portion of the frequency band for the link.

[0071] Table 4 lists the various frame structures that may be used to carry the transport channels. Each of these frame structures is described in further detail below. For clarity, the frame structures are described for the set of transport channels listed in Table 3.

Table 4

	Shared frequency band for downlink and uplink	Separate frequency bands for downlink and uplink
Time division	TDD-TDM frame structure	FDD-TDM frame structure
Code division	TDD-CDM frame structure	FDD-CDM frame structure

[0072] **FIG. 3A** illustrates an embodiment of a TDD-TDM frame structure 300a that may be used if a single frequency band is used for both the downlink and uplink. Data transmission occurs in units of TDD frames. Each TDD frame may be defined to span a particular time duration. The frame duration may be selected based on various factors such as, for example, (1) the bandwidth of the operating band, (2) the expected sizes of the PDUs for the transport channels, and so on. In general, a shorter frame duration may provide reduced delays. However, a longer frame duration may be more efficient since header and overhead may represent a smaller fraction of the frame. In a specific embodiment, each TDD frame has a duration of 2 msec.

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[0073] Each TDD frame is partitioned into a downlink phase and an uplink phase. The downlink phase is further partitioned into three segments for the three downlink transport channels - the BCH, FCCH, and FCH. The uplink phase is further partitioned into two segments for the two uplink transport channels - the RCH and RACH.

[0074] The segment for each transport channel may be defined to have either a fixed duration or a variable duration that can change from frame to frame. In an embodiment, the BCH segment is defined to have a fixed duration, and the FCCH, FCH, RCH, and RACH segments are defined to have variable durations.

[0075] The segment for each transport channel may be used to carry one or more protocol data units (PDUs) for that transport channel. In the specific embodiment shown in FIG. 3A, a BCH PDU is transmitted in a first segment 310, an FCCH PDU is transmitted in a second segment 320, and one or more FCH PDUs are transmitted in a third segment 330 of the downlink phase. On the uplink phase, one or more RCH PDUs are transmitted in a fourth segment 340 and one or more RACH PDUs are transmitted in a fifth segment 350 of the TDD frame.

[0076] Frame structure 300a represents a specific arrangement of the various transport channels within a TDD frame. This arrangement can provide certain benefits such as reduced delays for data transmission on the downlink and uplink. The BCH is transmitted first in the TDD frame since it carries system parameters that may be used for the PDUs of the other transport channels within the same TDD frame. The FCCH is transmitted next since it carries channel assignment information indicative of which user terminal(s) are designated to receive downlink data on the FCH and which user terminal(s) are designated to transmit uplink data on the RCH within the current TDD frame. Other TDD-TDM frame structures may also be defined and used for the MIMO WLAN system, and this is within the scope of the invention.

[0077] **FIG. 3B** illustrates an embodiment of an FDD-TDM frame structure 300b that may be used if the downlink and uplink are transmitted using two separate frequency bands. Downlink data is transmitted in a downlink frame 302a, and uplink data is transmitted in an uplink frame 302b. Each downlink and uplink frame may be defined to span a particular time duration (e.g., 2 msec). For simplicity, the downlink and uplink frames may be defined to have the same duration and may further be defined to be aligned at the frame boundaries. However, different frame durations and/or non-aligned (i.e., offset) frame boundaries may also be used for the downlink and uplink.

[0078] As shown in FIG. 3B, the downlink frame is partitioned into three segments for the three downlink transport channels. The uplink frame is partitioned into two segments for the two uplink transport channels. The segment for each transport channel may be defined to have a fixed or variable duration, and may be used to carry one or more PDUs for that transport channel.

[0079] In the specific embodiment shown in FIG. 3B, the downlink frame carries a BCH PDU, an FCCH PDU, and one or more FCH PDUs in segments 310, 320, and 330, respectively. The uplink frame carries one or more RCH PDUs and one or more RACH PDUs in segments 340 and 350, respectively. This specific arrangement may provide the benefits described above (e.g., reduced delays for data transmission). The transport channels may have different PDU formats, as described below. Other FDD-TDM frame structures may also be defined and used for the MIMO WLAN system, and this is within the scope of the invention.

[0080] **FIG. 3C** illustrates an embodiment of an FDD-CDM/FDM frame structure 300c that may also be used if the downlink and uplink are transmitted using separate frequency bands. Downlink data may be transmitted in a downlink frame 304a, and uplink data may be transmitted in an uplink frame 304b. The downlink and uplink frames may be defined to have the same duration (e.g., 2 msec) and aligned at the frame boundaries.

[0081] As shown in FIG. 3C, the three downlink transport channels are transmitted concurrently in the downlink frame, and the two uplink transport channels are transmitted concurrently in the uplink frame. For CDM, the transport channels for each link are "channelized" with different channelization codes, which may be Walsh codes, orthogonal variable spreading factor (OVSF) codes, quasi-orthogonal functions (QOF), and so on. For FDM, the transport channels for each link are assigned different portions of the frequency band for the link. Different amounts of transmit power may also be used for different transport channels in each link.

[0082] Other frame structures may also be defined for the downlink and uplink transport channels, and this is within the scope of the invention. Moreover, it is possible to use different types of frame structure for the downlink and uplink. For example, a TDM-based frame structure may be used for the downlink and a CDM-based frame structure may be used for the uplink.

[0083] In the following description, the MIMO WLAN system is assumed to use one frequency band for both downlink and uplink transmissions. For clarity, the TDD-TDM frame structure shown in FIG. 3A is used for the MIMO WLAN system. For clarity, a specific implementation of the TDD-TDM frame structure is described throughout the specification. For this implementation, the duration of each TDD frame is fixed at 2 msec, and the number of OFDM symbols per TDD frame is a function of the length of the cyclic prefix used for the OFDM symbols. The BCH has a fixed duration of 80 μsec and uses the 800 nsec cyclic prefix for the OFDM symbols transmitted. The remainder of the TDD frame contains 480 OFDM symbols if the 800 nsec cyclic prefix is used, and 533 OFDM symbols plus 1.2 μsec of excess time if the 400 nsec cyclic prefix is used. The excess time can be added to the guard interval at the end of the RACH segment. Other frame structures and other implementations may also be used, and this is within the scope of the invention.

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II. Transport Channels

[0084] The transport channels are used to send various types of data and may be categorized into two groups: common transport channels and dedicated transport channels. Because the common and dedicated transport channels are used for different purposes, different processing may be used for these two groups of transport channels, as described in further detail below.

[0085] **Common Transport Channels.** The common transport channels include the BCH, FCCH, and RACH. These transport channels are used to send data to or receive data from multiple user terminals. For improved reliability, the BCH and FCCH are transmitted by the access point using the diversity mode. On the uplink, the RACH is transmitted by the user terminals using the beam-steering mode (if supported by the user terminal). The BCH is operated at a known fixed rate so that the user terminals can receive and process the BCH without any additional information. The FCCH and RACH support multiple rates to allow for greater efficiency. As used herein, each "rate" or "rate set" is associated with a particular code rate (or coding scheme) and a particular modulation scheme.

[0086] **Dedicated Transport Channels.** The dedicated transport channels include the FCH and RCH. These transport channels are normally used to send user-specific data to or by specific user terminals. The FCH and RCH may be dynamically allocated to the user terminals as necessary and as available. The FCH may also be used in a broadcast mode to send overhead, page, and broadcast messages to the user terminals. In general, the overhead, page, and broadcast messages are transmitted prior to any user-specific data on the FCH.

[0087] **FIG. 4** illustrates an exemplary transmission on the BCH, FCCH, FCH, RCH, and RACH based on TDD-TDM frame structure 300a. In this embodiment, one BCH PDU 410 and one FCCH PDU 420 are transmitted in BCH segment 310 and FCCH segment 320, respectively. FCH segment 330 may be used to send one or more FCH PDUs 430, each of which may be intended for a specific user terminal or multiple user terminals. Similarly, one or more RCH PDUs 440 may be sent by one or more user terminals in RCH segment 340. The start of each FCH/RCH PDU is indicated by an FCH/RCH offset from the end of the preceding segment. A number of RACH PDUs 450 may be sent in RACH segment 350 by a number of user terminals to access the system and/or to send short messages, as described below.

[0088] For clarity, the transport channels are described for the specific TDD-TDM frame structure shown in FIGS. 3A and 4.

1. Broadcast Channel (BCH) - Downlink

[0089] The BCH is used by the access point to transmit a beacon pilot, a MIMO pilot, and system parameters to the user terminals. The beacon pilot is used by the user terminals to acquire system timing and frequency. The MIMO pilot is used by the user terminals to estimate the MIMO channel formed by the access point antennas and their own antennas. The beacon and MIMO pilots are described in further detail below. The system parameters specify various attributes of the downlink and uplink transmissions. For example, since the durations of the FCCH, FCH, RACH, and RCH segments are variable, the system parameters that specify the length of each of these segments for the current TDD frame are sent in the BCH.

[0090] **FIG. 5A** illustrates an embodiment of BCH PDU 410. In this embodiment, BCH PDU 410 includes a preamble portion 510 and a message portion 516. Preamble portion 510 further includes a beacon pilot portion 512 and a MIMO pilot portion 514. Portion 512 carries a beacon pilot and has a fixed duration of $T_{CP} = 8\mu sec$. Portion 514 carries a MIMO pilot and has a fixed duration of $T_{MP} = 32\mu sec$. Portion 516 carries a BCH message and has a fixed duration of $T_{BM} = 40\mu sec$. The duration of the BCH PDU is fixed at $T_{CP} + T_{MP} + T_{BM} = 80\mu sec$.

[0091] A preamble may be used to send one or more types of pilot and/or other information. A beacon pilot comprises a specific set of modulation symbols that is transmitted from all transmit antennas. A MIMO pilot comprises a specific set of modulation symbols that is transmitted from all transmit antennas with different orthogonal codes, which then allows the receivers to recover the pilot transmitted from each antenna. Different sets of modulation symbols may be used for the beacon and MIMO pilots. The generation of the beacon and MIMO pilots is described in further detail below.

[0092] The BCH message carries system configuration information. Table 5 lists the various fields for an exemplary BCH message format.

Table 5 - BCH Message

Fields/ Parameter Names	Length(bits)	Description
Frame Counter	4	TDD frame counter
Net ID	10	Network identifier (ID)
AP ID	6	Access point ID

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Table continued

Fields/ Parameter Names	Length(bits)	Description
AP Tx Lvl	4	Access point transmit level
AP Rx Lvl	3	Access point receive level
FCCH Length	6	Duration of FCCH (in units of OFDM symbols)
FCCH Rate	2	Physical layer rate of FCCH
FCH Length	9	Duration of FCH (in units of OFDM symbols)
RCH Length	9	Duration of RCH (in units of OFDM symbols)
RACH Length	5	Duration of RACH (in units of RACH slots)
RACH Slot Size	2	Duration of each RACH slot (in units of OFDM symbols)
RACH Guard Interval	2	Guard interval at the end of RACH
Cyclic Prefix Duration	1	Cyclic prefix duration
Page Bit	1	"0" = page message sent on FCH "1" = no page message sent
Broadcast Bit	1	"0" = broadcast message sent on FCH "1" = no broadcast message sent
RACH Acknowledgment Bit	1	"0" = RACH acknowledgment sent on FCH "1" = no RACH acknowledgment sent
CRC	16	CRC value for the BCH message
Tail Bits	6	Tail bits for convolutional encoder
Reserved	32	Reserved for future use

[0093] The Frame Counter value may be used to synchronize various processes at the access point and user terminals (e.g., the pilot, scrambling codes, cover code, and so on). A frame counter may be implemented with a 4-bit counter that wraps around. This counter is incremented at the start of each TDD frame, and the counter value is included in the Frame Counter field. The Net ID field indicates the identifier (ID) of the network to which the access point belongs. The AP ID field indicates the ID of the access point within the network ID. The AP Tx Lvl and AP Rx Lvl fields indicate the maximum transmit power level and the desired receive power level at the access point, respectively. The desired receive power level may be used by the user terminal to determine the initial uplink transmit power.

[0094] The FCCH Length, FCH Length, and RCH Length fields indicate the lengths of the FCCH, FCH, and RCH segments, respectively, for the current TDD frame. The lengths of these segments are given in units of OFDM symbols. The OFDM symbol duration for the BCH is fixed at 4.0 μsec. The OFDM symbol duration for all other transport channels (i.e., the FCCH, FCH, RACH, and RCH) is variable and depends on the selected cyclic prefix, which is specified by the Cyclic Prefix Duration field. The FCCH Rate field indicates the rate used for the FCCH for the current TDD frame.

[0095] The RACH Length field indicates the length of the RACH segment, which is given in units of RACH slots. The duration of each RACH slot is given by the RACH Slot Size field, in units of OFDM symbols. The RACH Guard Interval field indicates the amount of time between the last RACH slot and the start of the BCH segment for the next TDD frame. These various fields for the RACH are described in further detail below.

[0096] The Page Bit and Broadcast Bit indicate whether or not page messages and broadcast messages, respectively, are being sent on the FCH in the current TDD frame. These two bits may be set independently for each TDD frame. The RACH Acknowledgment Bit indicates whether or not acknowledgments for PDUs sent on the RACH in prior TDD frames are being sent on the FCCH in the current TDD frame.

[0097] The CRC field includes a CRC value for the entire BCH message. This CRC value may be used by the user terminals to determine whether the received BCH message is decoded correctly (i.e., good) or in error (i.e., erased). The Tail Bits field includes a group of zeros used to reset the convolutional encoder to a known state at the end of the BCH message.

[0098] As shown in Table 5, the BCH message includes a total of 120 bits. These 120 bits may be transmitted with 10 OFDM symbols using the processing described in detail below.

[0099] Table 5 shows a specific embodiment of the format for the BCH message. Other BCH message formats with fewer, additional, and/or different fields may also be defined and used, and this is within the scope of the invention.

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2. Forward Control Channel (FCCH) - Downlink

[0100] In an embodiment, the access point is able to allocate resources for the FCH and RCH on a per frame basis. The FCCH is used by the access point to convey the resource allocation for the FCH and RCH (i.e., the channel assignments).

[0101] **FIG. 5B** illustrates an embodiment of FCCH PDU 420. In this embodiment, the FCCH PDU includes only a portion 520 for an FCCH message. The FCCH message has a variable duration that can change from frame to frame, depending on the amount of scheduling information being carried on the FCCH for that frame. The FCCH message duration is in even number of OFDM symbols and given by the FCCH Length field on the BCH message. The duration of messages sent using the diversity mode (e.g., BCH and FCCH messages) is given in even number of OFDM symbols because the diversity mode transmits OFDM symbols in pairs, as described below.

[0102] In an embodiment, the FCCH can be transmitted using four possible rates. The specific rate used for the FCCH PDU in each TDD frame is indicated by the FCCH Phy Mode field in the BCH message. Each FCCH rate corresponds to a particular code rate and a particular modulation scheme and is further associated with a particular transmission mode, as shown in Table 26.

[0103] An FCCH message may include zero, one, or multiple information elements (IEs). Each information element may be associated with a specific user terminal and may be used to provide information indicative of the assignment of FCH/RCH resources for that user terminal. Table 6 lists the various fields for an exemplary FCCH message format.

Table 6 - FCCH Message

Fields/ Parameter Names	Length (bits)	Description
N_IE	6	Number of IEs included in the FCCH message
N_IE information elements, each including:		
IE Type	4	IE type
MAC ID	10	ID assigned to the user terminal
Control Fields	48 or 72	Control fields for channel assignment
Padding Bits	Variable	Pad bits to achieve even number of OFDM symbols in the FCCH message
CRC	16	CRC value for the FCCH message
Tail Bits	6	Tail bits for convolutional encoder

[0104] The N_IE field indicates the number of information elements included in the FCCH message sent in the current TDD frame. For each information element (IE) included in the FCCH message, the IE Type field indicates the particular type of this IE. A number of IE types are defined for use to allocate resources for different types of transmissions, as described below.

[0105] The MAC ID field identifies the specific user terminal for which the information element is intended. Each user terminal registers with the access point at the start of a communication session and is assigned a unique MAC ID by the access point. This MAC ID is used to identify the user terminal during the session.

[0106] The Control Fields are used to convey channel assignment information for the user terminal and are described in detail below. The Padding Bits field includes a sufficient number of padding bits so that the overall length of the FCCH message is an even number of OFDM symbols. The FCCH CRC field includes a CRC value that may be used by the user terminals to determine whether the received FCCH message is decoded correctly or in error. The Tail Bits field includes zeros used to reset the convolutional encoder to a known state at the end of the FCCH message. Some of these fields are described in further detail below.

[0107] A number of transmission modes are supported by the MIMO WLAN system for the FCH and RCH, as indicated in Table 1. Moreover, a user terminal may be active or idle during a connection. Thus, a number of types of IE are defined for use to allocate FCH/RCH resources for different types of transmissions. Table 7 lists an exemplary set of IE types.

Table 7 - FCCH IE Types

IE Type	IE Size (bits)	IE Type	Description
0	48	Diversity Mode	Diversity mode only
1	72	Spatial Multiplexing Mode	Spatial multiplexing mode - variable rate services

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Table continued

IE Type	IE Size (bits)	IE Type	Description
2	48	Idle Mode	Idle state - variable rate services
3	48	RACH Acknowledgment	RACH acknowledgment - diversity mode
4		Beam Steering Mode	Beam steering mode
5-15	-	Reserved	Reserved for future use

[0108] For IE types 0, 1 and 4, resources are allocated to a specific user terminal for both the FCH and RCH (i.e., in channel pairs). For IE type 2, minimal resources are allocated to the user terminal on the FCH and RCH to maintain up-to-date estimate of the link: An exemplary format for each IE type is described below. In general, the rates and durations for the FCH and RCH can be independently assigned to the user terminals.

A. IE Type 0, 4 - Diversity/Beam-Steering Mode

[0109] IE type 0 and 4 are used to allocate FCH/RCH resources for the diversity and beam-steering modes, respectively. For fixed low-rate services (e.g., voice), the rate remains fixed for the duration of the call. For variable rate services, the rate may be selected independently for the FCH and RCH. The FCCH IE indicates the location of the FCH and RCH PDUs assigned to the user terminal. Table 8 lists the various fields of an exemplary IE Type 0 and 4 information element.

Table 8 - FCCH IE Type 0 and 4

Fields/Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from start of the TDD frame (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
FCH Rate	4	Rate for the FCH
RCH Offset	9	RCH offset from start of the TDD frame (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
RCH Rate	4	Rate for the RCH
RCH Timing Adjustment	2	Timing adjustment parameter for RCH
RCH Power Control	2	Power control bits for RCH

[0110] The FCH and RCH Offset fields indicate the time offset from the beginning of the current TDD frame to the start of the FCH and RCH PDUs, respectively, assigned by the information element. The FCH and RCH Rate fields indicate the rates for the FCH and RCH, respectively.

[0111] The FCH and RCH Preamble Type fields indicate the size of the preamble in the FCH and RCH PDUs, respectively. Table 9 lists the values for the FCH and RCH Preamble Type fields and the associated preamble sizes.

Table 9 - Preamble Type

Type	Bits	Preamble Size
0	00	0 OFDM symbol
1	01	1 OFDM symbol
2	10	4 OFDM symbols
3	11	8 OFDM symbols

[0112] The RCH Timing Adjustment field includes two bits used to adjust the timing of the uplink transmission from the user terminal identified by the MAC ID field. This timing adjustment is used to reduce interference in a TDD-based

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frame structure (such as the one shown in FIG. 3A) where the downlink and uplink transmissions are time division duplexed. Table 10 lists the values for the RCH Timing Adjustment field and the associated actions.

Table 10 - RCH Timing Adjustment

Bits	Description
00	Maintain current timing
01	Advance uplink transmit timing by 1 sample
10	Delay uplink transmit timing by 1 sample
11	Not used

[0113] The RCH Power Control field includes two bits used to adjust the transmit power of the uplink transmission from the identified user terminal. This power control is used to reduce interference on the uplink. Table 11 lists the values for the RCH Power Control field and the associated actions.

Table 11 - RCH Power Control

Bits	Description
00	Maintain current transmit power
01	Increase uplink transmit power by δ dB, where δ is a system parameter.
10	Decrease uplink transmit power by δ dB, where δ is a system parameter.
11	Not used

[0114] The channel assignment for the identified user terminal may be provided in various manners. In an embodiment, the user terminal is assigned FCH/RCH resources for only the current TDD frame. In another embodiment, the FCH/RCH resources are assigned to the terminal for each TDD frame until canceled. In yet another embodiment, the FCH/RCH resources are assigned to the user terminal for every *n*-th TDD frame, which is referred to as "decimated" scheduling of TDD frames. The different types of assignment may be indicated by an Assignment Type field in the FCCH information element.

B. IE Type 1 - Spatial Multiplexing Mode

[0115] IE type 1 is used to allocate FCH/RCH resources to user terminals using the spatial multiplexing mode. The rate for these user terminals is variable, and may be selected independently for the FCH and RCH. Table 12 lists the various fields of an exemplary IE type 1 information element.

Table 12 - FCCH IE Type 1

Fields/ Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from end of FCCH (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
FCH Spatial Channel 1 Rate	4	Rate for the FCH for spatial channel 1
FCH Spatial Channel 2 Rate	4	Rate for the FCH for spatial channel 2
FCH Spatial Channel 3 Rate	4	Rate for the FCH for spatial channel 3
FCH Spatial Channel 4 Rate	4	Rate for the FCH for spatial channel 4
RCH Offset	9	RCH offset from end of FCH (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
RCH Spatial Channel 1 Rate	4	Rate for the RCH for spatial channel 1

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Table continued

Fields/ Parameter Names	Length (bits)	Description
RCH Spatial Channel 2 Rate	4	Rate for the RCH for spatial channel 2
RCH Spatial Channel 3 Tate	4	Rate for the RCH for spatial channel 3
RCH Spatial Channel 4 Rate	4	Rate for the RCH for spatial channel 4
RCH Timing Adjustment	2	Timing adjustment parameter for RCH
Reserved	2	Reserved for future use

[0116] For IE type 1, the rate for each spatial channel may be selected independently on the FCH and RCH. The interpretation of the rates for the spatial multiplexing mode is general in that it can specify the rate per spatial channel (e.g., for up to four spatial channels for the embodiment shown in Table 12). The rate is given per eigenmode if the transmitter performs spatial processing to transmit data on the eigenmodes. The rate is given per antenna if the transmitter simply transmits data from the transmit antennas and the receiver performs the spatial processing to isolate and recover the data (for the non-steered spatial multiplexing mode).

[0117] The information element includes the rates for all enabled spatial channels and zeros for the ones not enabled. User terminals with less than four transmit antennas set the unused FCH/RCH Spatial Channel Rate fields to zero. Since the access point is equipped with four transmit/receive antennas, user terminals with more than four transmit antennas may use them to transmit up to four independent data streams.

C. IE Type 2 - Idle Mode

[0118] IE type 2 is used to provide control information for user terminals operating in an *Idle* state (described below). In an embodiment, when a user terminal is in the *Idle* state, steering vectors used by the access point and user terminal for spatial processing are continually updated so that data transmission can start quickly if and when resumed. Table 13 lists the various fields of an exemplary IE type 2 information element.

Table 13 - FCCH IE Type 2

Fields/Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from end of FCCH (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
RCH Offset	9	RCH offset from end of FCH (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
Reserved	12	Reserved for future use

D. IE Type 3 - RACH Quick Acknowledgment

[0119] IE type 3 is used to provide quick acknowledgment for user terminals attempting to access the system via the RACH. To gain access to the system or to send a short message to the access point, a user terminal may transmit an RACH PDU on the uplink. After the user terminal sends the RACH PDU, it monitors the BCH to determine if the RACH Acknowledgement Bit is set. This bit is set by the access point if any user terminal was successful in accessing the system and an acknowledgment is being sent for at least one user terminal on the FCCH. If this bit is set, then the user terminal processes the FCCH for acknowledgment sent on the FCCH. IE Type 3 information elements are sent if the access point desires to acknowledge that it correctly decoded the RACH PDUs from the user terminals without assigning resources. Table 14 lists the various fields of an exemplary IE Type 3 information element.

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Table 14 - FCCH IE Type 3

Fields/ Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to user terminal
Reserved	34	Reserved for future use

[0120] A single or multiple types of acknowledgment may be defined and sent on the FCCH. For example, a quick acknowledgment and an assignment-based acknowledgment may be defined. A quick acknowledgment may be used to simply acknowledge that the RACH PDU has been received by the access point but that no FCH/RCH resources have been assigned to the user terminal. An assignment-based acknowledgment includes assignments for the FCH and/or RCH for the current TDD frame.

[0121] The FCCH may be implemented in other manners and may also be transmitted in various ways. In one embodiment, the FCCH is transmitted at a single rate that is signaled in the BCH message. This rate may be selected, for example, based on the lowest signal-to-noise-and-interference ratios (SNRs) of all user terminals for which the FCCH is being sent in the current TDD frame. Different rates may be used for different TDD frames depending on the channel conditions of the recipient user terminals in each TDD frame.

[0122] In another embodiment, the FCCH is implemented with multiple (e.g., four) FCCH subchannels. Each FCCH subchannel is transmitted at a different rate and is associated with a different required SNR in order to recover the subchannel. The FCCH subchannels are transmitted in order from lowest rate to highest rate. Each FCCH subchannel may or may not be transmitted in a given TDD frame. The first FCCH subchannel (with the lowest rate) is transmitted first and can be received by all user terminals. This FCCH subchannel can indicate whether or not each of the remaining FCCH subchannels will be transmitted in the current TDD frame. Each user terminal can process the transmitted FCCH subchannels to obtain its FCCH information element. Each user terminal can terminate processing of the FCCH if any of the following occurs: (1) failure to decode the current FCCH subchannel, (2) reception of its FCCH information element in the current FCCH subchannel, or (3) all transmitted FCCH subchannels have been processed. A user terminal can terminate processing of the FCCH as soon as it encounters FCCH decoding failure because the FCCH subchannels are transmitted at ascending rates and the user terminal is unlikely to be able to decode subsequent FCCH subchannels transmitted at higher rates.

3. Random Access Channel (RACH) - Uplink

[0123] The RACH is used by the user terminals to gain access to the system and to send short messages to the access point. The operation of the RACH is based on a slotted Aloha random access protocol, which is described below.

[0124] **FIG. 5C** illustrates an embodiment of RACH PDU 450. In this embodiment, the RACH PDU includes a preamble portion 552 and a message portion 554. Preamble portion 552 may be used to send a steered reference (i.e., a steered pilot), if the user terminal is equipped with multiple antennas. The steered reference is a pilot comprised of a specific set of modulation symbols that is subjected to spatial processing prior to transmission on the uplink. The spatial processing allows the pilot to be transmitted on a specific eigenmode of the MIMO channel. The processing for the steered reference is described in further detail below. Preamble portion 552 has a fixed duration of at least 2 OFDM symbols. Message portion 554 carries an RACH message and has a variable duration. The duration of the RACH PDU is thus variable.

[0125] In an embodiment, four different rates are supported for the RACH. The specific rate used for each RACH message is indicated by a 2-bit RACH data rate indicator (DRI), which is embedded in the preamble portion of the RACH PDU, as shown in FIG. 5C. In an embodiment, four different message sizes are also supported for the RACH. The size of each RACH message is indicated by a Message Duration field included in the RACH message. Each RACH rate supports 1, 2, 3 or all 4 message sizes. Table 15 lists the four RACH rates, their associated coding and modulation parameters, and the message sizes supported by these RACH rates.

Table 15

RACH Rates				RACH Message Sizes (in bits and OFDM symbols)			
bps/Hz	Code Rate	Modulation	DRI	96 bits	192 bits	384 bits	768 bits
0.25	0.25	BPSK	(1,1)	8	n/a	n/a	n/a
0.5	0.5	BPSK	(1,-1)	4	8	n/a	n/a
1	0.5	QPSK	(-1, 1)	2	4	8	n/a

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Table continued

RACH Rates				RACH Message Sizes (in bits and OFDM symbols)			
bps/Hz	Code Rate	Modulation	DRI	96 bits	192 bits	384 bits	768 bits
2	0.5	16 QAM	(-1, -1)	1	2	4	8

[0126] The RACH message carries short messages and access requests from the user terminal. Table 16 lists the various fields of an exemplary RACH message format and the size of each field for each of the four different message sizes.

Table 16

Fields/Parameter Names	RACH Message Sizes				Description
	96 bits	192 bits	384 bits	768 bits	
Message Duration	2	2	2	2	Duration of message
MAC PDU Type	4	4	4	4	RACH message type
MAC ID	10	10	10	10	MAC ID
Slot ID	6	6	6	6	Tx Slot ID
Payload	44	140	332	716	Info bits
CRC	24	24	24	24	CRC value for the RACH message
Tail Bits	6	6	6	6	Tail bits

[0127] The Message Duration field indicates the size of the RACH message. The MAC PDU Type field indicates the RACH message type. The MAC ID field contains the MAC ID that uniquely identifies the user terminal sending the RACH message. During initial system access, a unique MAC ID has not been assigned to the user terminal. In this case, a registration MAC ID (e.g., a specific value reserved for registration purpose) may be included in the MAC ID field. The Slot ID field indicates the starting RACH slot on which the RACH PDU was sent (the RACH timing and transmission is described below). The Payload field includes the information bits for the RACH message. The CRC field contains a CRC value for the RACH message, and the Tail Bits field is used to reset the convolutional encoder for the RACH. The operation of the RACH in conjunction with the BCH and FCCH for system access is described in further detail below.

[0128] The RACH may also be implemented with a "fast" RACH (F-RACH) and a "slow" RACH (S-RACH). The F-RACH and S-RACH can be designed to efficiently support user terminals in different operating states. For example, the F-RACH may be used by user terminals that (1) have registered with the system, (2) can compensate for their round trip delays (RTDs) by properly advancing their transmit timing, and (3) achieve the required SNR for operation on the F-RACH. The S-RACH may be used by user terminals that cannot use the F-RACH for any reasons.

[0129] Different designs may be used for the F-RACH and S-RACH to facilitate rapid access to the system whenever possible and to minimize the amount of system resources needed to implement random access. For example, the F-RACH can use a shorter PDU, employ a weaker coding scheme, require F-RACH PDUs to arrive approximately time-aligned at the access point, and utilize a slotted Aloha random access scheme. The S-RACH can use a longer PDU, employ a stronger coding scheme, allow S-RACH PDUs to arrive non-aligned in time at the access point, and utilize an unslotted Aloha random access scheme.

[0130] For simplicity, the following description assumes that a single RACH is used for the MIMO WLAN system.

4. Forward Channel (FCH) - Downlink

[0131] The FCH is used by the access point to transmit user-specific data to specific user terminals and page/broadcast messages to multiple user terminals. The FCH may also be used to transmit pilot to user terminals. The FCH can be allocated on a per frame basis. A number of FCH PDU types are provided to accommodate different uses of the FCH. Table 17 lists an exemplary set of FCH PDU types.

Table 17 - FCH PDU Types

Code	FCH PDU Type	Description
0	Message Only	FCH broadcast/page service/user message

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Table continued

Code	FCH PDU Type	Description
1	Message and Preamble	FCH user message
2	Preamble Only	FCH *Idle* state

[0132] FCH PDU Type 0 is used to send page/broadcast messages and user messages/packets on the FCH and only includes the message/packet. (Data for a specific user terminal may be sent as a message or a packet, and these two terms are used interchangeably herein.) FCH PDU Type 1 is used to send user packets and includes a preamble. FCH PDU Type 2 includes only the preamble and no message/packet, and is associated with *Idle* state FCH traffic.

[0133] **FIG. 5D** illustrates an embodiment of an FCH PDU 430a for FCH PDU Type 0. In this embodiment, FCH PDU 430a includes only a message portion 534a for a page/broadcast message or a user packet. The message/packet can have variable length, which is given by the FCH Message Length field in the FCH PDU. The message length is given in integer number of PHY frames (described below). The rate and transmission mode for the page/broadcast message are specified and described below. The rate and transmission mode for the user packet are specified in the associated FCCH information element.

[0134] **FIG. 5E** illustrates an embodiment of an FCH PDU 430b for FCH PDU Type 1. In this embodiment, FCH PDU 430b includes a preamble portion 532b and a message/packet portion 534b. Preamble portion 532b is used to send a MIMO pilot or a steered reference and has a variable length, which is given by the FCH Preamble Type field in the associated FCCH information element. Portion 534b is used to send an FCH packet and also has a variable length (in integer number of PHY frames), which is given by the FCH Message Length field in the FCH PDU. The FCH packet is sent using the rate and transmission mode specified by the associated FCCH information element.

[0135] **FIG. 5F** illustrates an embodiment of an FCH PDU 430c for FCH PDU Type 2. In this embodiment, FCH PDU 430c includes only a preamble portion 532c and no message portion. The length of the preamble portion is indicated by the FCCH IE. The FCH PDU Type 2 may be used to allow the user terminal to update its channel estimate while in the *Idle* state.

[0136] A number of FCH Message types are provided to accommodate different uses of the FCH. Table 18 lists an exemplary set of FCH Message types.

Table 18 - FCH Message Types

Code	FCH Message Type	Description
0	Page Message	Page message - diversity mode, rate = 0.25 bps/Hz
1	Broadcast Message	Broadcast message - diversity mode, rate = 0.25 bps/Hz
2	User Packet	Dedicated channel operation - user terminal specific PDU, rate specified in the FCCH
3-15	Reserved	Reserved for future use

[0137] A page message may be used to page multiple user terminals and is sent using FCH PDU Type 0. If the Page Bit in the BCH message is set, then one or more FCH PDUs with page messages (or "Page PDUs") are sent first on the FCH. Multiple Page PDUs may be sent in the same frame. Page PDUs are transmitted using the diversity mode and the lowest rate of 0.25 bps/Hz to increase the likelihood of correct reception by the user terminals.

[0138] A broadcast message may be used to send information to multiple user terminals and is sent using FCH PDU Type 0. If the Broadcast Bit in the BCH message is set, then one or more FCH PDUs with broadcast messages (or "Broadcast PDUs") are sent on the FCH immediately following any Page PDUs sent on the FCH. The Broadcast PDUs are also transmitted using the diversity mode and the lowest rate of 0.25 bps/Hz to increase the likelihood of correct reception.

[0139] A user packet may be used to send user-specific data, and may be sent using FCH PDU Type 1 or 2. User PDUs of Type 1 and 2 are sent on the FCH following any Page and Broadcast PDUs sent on the FCH. Each User PDU may be transmitted using the diversity, beam-steering, or spatial multiplexing mode. The FCCH information element specifies the rate and transmission mode used for each User PDU sent on the FCH.

[0140] A message or packet sent on the FCH comprises an integer number of PHY frames. In an embodiment and as described below, each PHY frame may include a CRC value that permits individual PHY frames in an FCH PDU to be checked and retransmitted if necessary. For asynchronous services, the RLP may be employed for segmentation, retransmission, and reassembly of PHY frames within a given FCH PDU. In another embodiment, a CRC value is provided for each message or packet, instead of each PHY frame.

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[0141] **FIG. 6** illustrates an embodiment of the structure for an FCH packet 534. The FCH packet comprises an integer number of PHY frames 610. Each PHY frame includes a payload field 622, a CRC field 624, and a tail bit field 626. The first PHY frame for the FCH packet further includes a header field 620, which indicates the message type and duration. The last PHY frame in the FCH packet further includes a pad bit field 628, which contains zero padding bits at the end of the payload in order to fill the last PHY frame. In an embodiment, each PHY frame comprises 6 OFDM symbols. The number of bits included in each PHY frame is dependent on the rate used for that PHY frame.

[0142] Table 19 lists the various fields for an exemplary FCH PDU format for FCH PDU Types 0 and 1.

Table 19 - FCH PDU Format

	Fields/Parameter Names	Length (bits)	Description
First PHY frame	FCH Message Type	4	FCH message type
	FCH Message Length	16	Number of bytes in FCH PDU
	Payload	Variable	Payload bits
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder
Each Middle PHY frame	Payload	Variable	Payload bits
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder
Last PHY frame	Payload	Variable	Payload bits
	Pad bits	Variable	Pad bits to fill out PHY frame
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder

[0143] The FCH Message Type and FCH Message Length fields are sent in the header of the first PHY frame of the FCH PDU. The payload, CRC, and tail bits fields are included in each PHY frame. The payload portion of each FCH PDU carries the information bits for the page/broadcast message or user-specific packet. Pad bits are used to fill the last PHY frame of the FCH PDU, if required.

[0144] A PHY frame may also be defined to comprise some other number of OFDM symbols (e.g., one, two, four, eight, and so on). The PHY frame may be defined with even number of OFDM symbols because OFDM symbols are transmitted in pairs for the diversity mode, which may be used for the FCH and RCH. The PHY frame size may be selected based on the expected traffic such that inefficiency is minimized. In particular, if the frame size is too large, then inefficiency results from using a large PHY frame to send a small amount of data. Alternatively, if the frame size is too small, then the overhead represents a larger fraction of the frame.

5. Reverse Channel (RCH) - Uplink

[0145] The RCH is used by the user terminals to transmit uplink data and pilot to the access point. The RCH may be allocated on a per TDD frame basis. One or more user terminals may be designated to transmit on the RCH in any given TDD frame. A number of RCH PDU types are provided to accommodate different operating modes on the RCH. Table 20 lists an exemplary set of RCH PDU types.

Table 20 - RCH PDU Types

Code	RCH PDU Type	Description
0	Message Only	RCH user message, no preamble
1	Message and Preamble, not Idle	RCH user message, with preamble
2	Message and Preamble, Idle	RCH idle state message with preamble

[0146] RCH PDU Type 0 is used to send a message/packet on the RCH and does not include a preamble. RCH PDU Type 1 is used to send a message/packet and includes a preamble. RCH PDU Type 2 includes a preamble and a short

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message, and is associated with *Idle* state RCH traffic.

[0147] **FIG. 5D** illustrates an embodiment of an RCH PDU for RCH PDU Type 0. In this embodiment, the RCH PDU includes only a message portion 534a for a variable-length RCH packet, which is given in integer number of PHY frames by the RCH Message Length field in the RCH PDU. The rate and transmission mode for the RCH packet are specified in the associated FCCH information element.

[0148] **FIG. 5E** illustrates an embodiment of an RCH PDU for RCH PDU Type 1. In this embodiment, the RCH PDU includes a preamble portion 532b and a packet portion 534b. Preamble portion 532b is used to send a reference (e.g., a MIMO pilot or a steered reference) and has a variable length, which is given by the RCH Preamble Type field in the associated FCCH information element. Portion 534b is used to send an RCH packet and also has a variable length, which is given by the RCH Message Length field in the RCH PDU. The RCH packet is sent using the rate and transmission mode specified in the associated FCCH information element.

[0149] **FIG. 5G** illustrates an embodiment of an RCH PDU 350d for RCH PDU Type 2. In this embodiment, the RCH PDU includes a preamble portion 532d and a message portion 536d. Preamble portion 532d is used to send a reference and has a length of 1, 4 or 8 OFDM symbols. Portion 536d is used to send a short RCH message and has a fixed length of one OFDM symbol. The short RCH message is sent using a specific rate and transmission mode (e.g., rate 1/2 or rate 1/4 and BPSK modulation).

[0150] A packet sent on the RCH (for PDU Types 0 and 1) comprises an integer number of PHY frames. The structure for an RCH packet (for PDU Types 0 and 1) is shown in FIG. 6, and is the same as for the FCH packet. The RCH packet comprises an integer number of PHY frames 610. Each PHY frame includes payload field 622, an optional CRC field 624, and tail bit field 626. The first PHY frame in the RCH packet further includes header field 620, and the last PHY frame in the packet further includes pad bit field 628.

[0151] Table 21 lists the various fields for an exemplary RCH PDU format for RCH PDU Types 0 and 1.

Table 21 - RCH PDU Format (PDU Types 0 and 1)

	Fields/Parameter Names	**Length** (bits)	**Description**
First PHY frame	RCH Message Type	4	RCH message type
	RCH Message Length	16	Number of bytes in RCH PDU
	FCH Rate Indicator	16	Indicate maximum rate for each spatial channel on FCH
	Payload	Variable	Payload bits
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder
Each Middle PHY frame	Payload	Variable	Payload bits
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder
Last PHY frame	Payload	Variable	Payload bits
	Pad bits	Variable	Pad bits to fill out PHY frame
	CRC	16	CRC value for PHY frame (optional)
	Tail Bits	6	Tail bits for convolutional encoder

[0152] The RCH Message Type, RCH Message Length, and FCH Rate Indicator fields are sent in the header of the first PHY frame of the RCH PDU. The FCH Rate Indicator field is used to convey FCH rate information (e.g., the maximum rates supported by each of the spatial channels) to the access point.

[0153] Table 22 lists the various fields for an exemplary RCH PDU format for RCH PDU Type 2.

Table 22 - RCH Message for RCH PDU Type 2

Fields/Parameter Names	**Length** (bits)	**Description**
FCH Rate Indicator	16	Indicate maximum rate for each spatial channel on FCH
RCH Request	1	User terminal request to send additional data

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Table continued

Fields/Parameter Names	Length (bits)	Description
Reserved	1	Reserved for future use
Tail Bits	6	Tail bits for convolutional encoder

The RCH Request field is used by the user terminal to request additional capacity on the uplink. This short RCH message does not include a CRC and is transmitted in a single OFDM symbol.

6. Dedicated Channel Activity

[0154] Data transmission on the FCH and RCH can occur independently. Depending on the transmission modes selected for use for the FCH and RCH, one or multiple spatial channels (for the beam-steering and diversity modes) may be active and used for data transmission for each dedicated transport channel. Each spatial channel may be associated with a specific rate.

[0155] When only the FCH or only the RCH has all four rates set to zero, the user terminal is idle on that link. The idle terminal still transmits an idle PDU on the RCH. When both the FCH and RCH have all four rates set to zero, both the access point and user terminal are off and not transmitting. User terminals with less than four transmit antennas set the unused rate fields to zero. User terminals with more than four transmit antennas use no more than four spatial channels to transmit data. Table 23 shows the transmission state and channel activity when the rates on all four spatial channels of either the FCH or RCH (or both) are set to zero.

Table 23

FCH Rates	RCH Rates	Channel Activity	Transmission State
At least one rate on FCH ≠ 0	At least one rate on RCH ≠ 0	FCH and RCH are active	FCH and/or RCH are transmitting
At least one rate on FCH ≠ 0	All rates on RCH = 0	FCH active, RCH idle	
All rates on FCH = 0	At least one rate on RCH ≠ 0	FCH idle, RCH active	
All rates on FCH = 0	All rates on RCH = 0	FCH and RCH are OFF	No transmissions

[0156] There may also be a situation where both the RCH and FCH are idle (i.e., not transmitting data) but still transmitting preamble. This is referred to as the *Idle* state. The control fields used to support a user terminal in the *Idle* state are provided in an FCCH IE Type 2 information element, which is shown in Table 13.

7. Alternative Designs

[0157] For clarity, specific PDU types, PDU structures, message formats, and so on, have been described for an exemplary design. Fewer, additional, and/or different types, structures, and formats may also be defined for use, and this is within the scope of the invention.

III. OFDM Subband Structures

[0158] In the above description, the same OFDM subband structure is used for all of the transport channels. Improved efficiency may be achieved by using different OFDM subband structures for different transport channels. For example, a 64-subband structure may be used for some transport channels, a 256-subband structure may be used for some other transport channels, and so on. Moreover, multiple OFDM subband structures may be used for a given transport channel.

[0159] For a given system bandwidth of W, the duration of an OFDM symbol is dependent on the number of total subbands. If the total number of subbands is N, then the duration of each transformed symbol (without a cyclic prefix) is N/W μsec (if W is given in MHz). A cyclic prefix is added to each transformed symbol to form a corresponding OFDM symbol. The length of the cyclic prefix is determined by the expected delay spread of the system. The cyclic prefix represents overhead, which is needed for each OFDM symbol in order to combat a frequency selective channel. This overhead represents a larger percentage of the OFDM symbol if the symbol is short and a smaller percentage if the symbol is long.

[0160] Since different transport channels may be associated with different types of traffic data, a suitable OFDM subband structure may be selected for use for each transport channel to match the expected traffic data type. If a large

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amount of data is expected to be transmitted on a given transport channel, then a larger subband structure may be defined for use for the transport channel. In this case, the cyclic prefix would represent a smaller percentage of the OFDM symbol and greater efficiency may be achieved. Conversely, if a small amount of data is expected to be transmitted on a given transport channel, than a smaller subband structure may be defined for use for the transport channel. In this case, even though the cyclic prefix represents a larger percentage of the OFDM symbol, greater efficiency may still be achieved by reducing the amount of excess capacity by using a smaller size OFDM symbol. The OFDM symbol may thus be viewed as a "box car" that is used to send data, and the proper size "box car" may be selected for each transport channel depending on the amount of data expected to be sent.

[0161] For example, for the embodiment described above, the data on the FCH and RCH is sent in PHY frames, each of which comprises 6 OFDM symbols. In this case, another OFDM structure may be defined for use for the FCH and RCH. For example, a 256-subband structure may be defined for the FCH and RCH. A "large" OFDM symbol for the 256-subband structure would be approximately four times the duration of a "small" OFDM symbol for the 64-subband structure but would have four times the data-carrying capacity. However, only one cyclic prefix is needed for one large OFDM symbol, whereas four cyclic prefixes are needed for the equivalent four small OFDM symbols. Thus, the amount of overhead for the cyclic prefixes may be reduced by 75% by the use of the larger 256-subband structure.

[0162] This concept may be extended so that different OFDM subband structures may be used for the same transport channel. For example, the RCH supports different PDU types, each of which may be associated with a certain size. In this case, a larger subband structure may be used for a larger-size RCH PDU type, and a smaller subband structure may be used for a smaller-size RCH PDU type. A combination of different subband structures may also be used for a given PDU. For example, if one long OFDM symbol is equivalent to four short OFDM symbols, then a PDU may be sent using N_{large} large OFDM symbols and N_{small} small OFDM symbols, where $N_{large} \geq 0$ and $3 \geq N_{small} \geq 0$.

[0163] Different OFDM subband structures are associated with OFDM symbols of different lengths. Thus, if different OFDM subband structures are used for different transport channels (and/or for the same transport channel), then the FCH and RCH offsets for the FCH and RCH PDUs would need to be specified with the proper time resolution, which is smaller than an OFDM symbol period. In particular, the time increment for the FCH and RCH PDUs may be given in integer numbers of cyclic prefix length, instead of OFDM symbol period.

IV. Rates and Transmission Modes

[0164] The transport channels described above are used to send various types of data for various services and functions. Each transport channel may be designed to support one or more rates and one or more transmission modes.

1. Transmission Modes

[0165] A number of transmission modes are supported for the transport channels. Each transmission mode is associated with specific spatial processing at the transmitter and receiver, as described below. Table 24 lists the transmission mode(s) supported by each of the transport channels.

Table 24

Transport Channels	Transmission Modes			
	SIMO	Tx Diversity	Beam-Steering	Spatial Multiplexing
BCH	-	X		-
FCCH	-	X	-	-
RACH	X	-	X	-
FCH	-	X	X	X
RCH	X	X	X	X

For the diversity mode, each data symbol is transmitted redundantly over multiple transmit antennas, multiple subbands, multiple symbol periods, or a combination thereof to achieve spatial, frequency, and/or time diversity. For the beam-steering mode, a single spatial channel is used for data transmission (typically the best spatial channel), and each data symbol is transmitted on the single spatial channel using full transmit power available for the transmit antennas. For the spatial multiplexing mode, multiple spatial channels are used for data transmission, and each data symbol is transmitted on one spatial channel, where a spatial channel may correspond to an eigenmode, a transmit antenna, and so on. The beam-steering mode may be viewed as a special case of the spatial multiplexing mode whereby only one spatial channel

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is used for data transmission.

[0166] The diversity mode may be used for the common transport channels (BCH and FCCH) for the downlink from the access point to the user terminals. The diversity mode may also be used for the dedicated transport channels (FCH and RCH). The use of the diversity mode on the FCH and RCH may be negotiated at call setup. The diversity mode transmits data on one "spatial mode" using a pair of antennas for each subband.

[0167] The beam-steering mode may be employed on the RACH by user terminals with multiple transmit antennas. A user terminal can estimate the MIMO channel based on the MIMO pilot sent on the BCH. This channel estimate may then be used to perform beam-steering on the RACH for system accesses. The beam-steering mode may also be used for the dedicated transport channels (FCH and RCH). The beam-steering mode may be able to achieve higher received signal-to-noise-and-interference ratio (SNR) at the receiver than the diversity mode by exploiting the gain of the antenna array at the transmitter. In addition, the preamble portion of the PDU may be reduced since the steered reference only includes symbols for a single "steered" antenna. The diversity mode may also be used for the RACH.

[0168] The spatial multiplexing mode may be used for the FCH and RCH to achieve greater throughput, when supported by the channel conditions. The spatial multiplexing and beam-steering modes are reference driven and require closed-loop control for proper operation. As such, a user terminal is allocated resources on both the FCH and RCH to support the spatial multiplexing mode. Up to four spatial channels may be supported on the FCH and RCH (limited by the number of antennas at the access point).

2. Coding and Modulation

[0169] A number of different rates are supported for the transport channels. Each rate is associated with a particular code rate and a particular modulation scheme, which collectively results in a particular spectral efficiency (or data rate). Table 25 lists the various rates supported by the system.

Table 25

Rate Word	Spectral Efficiency (bps/Hz)	Code Rate	Modulation Scheme	Info bits/ OFDM symbol	Code bits/ OFDM symbol
0000	0.0	-	off	-	-
0001	0.25	1/4	BPSK	12	48
0010	0.5	1/2	BPSK	24	48
0011	1.0	1/2	QPSK	48	96
0100	1.5	3/4	QPSK	72	96
0101	2.0	1/2	16 QAM	96	192
0110	2.5	5/8	16 QAM	120	192
0111	3.0	3/4	16 QAM	144	192
1000	3.5	7/12	64 QAM	168	288
1001	4.0	2/3	64 QAM	192	288
1010	4.5	3/4	64 QAM	216	288
1011	5.0	5/6	64 QAM	240	288
1100	5.5	11/16	256 QAM	264	384
1101	6.0	3/4	256 QAM	288	384
1110	6.5	13/16	256 QAM	312	384
1111	7.0	7/8	256 QAM	336	384

[0170] Each common transport channel supports one or more rates and one transmission mode (or possibly more, as may be the case for the RACH). The BCH is transmitted at a fixed rate using the diversity mode. The FCCH may be transmitted at one of four possible rates, as indicated by the FCCH Phy Mode field in the BCH message, using the diversity mode. In one embodiment, the RACH may be transmitted at one of four possible rates, as indicated by the RACH DRI embedded in the preamble of the RACH PDU, and each RACH message is one of four possible sizes. In

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another embodiment, the RACH is transmitted at a single rate. Table 26 lists the coding, modulation, and transmission parameters and the message sizes supported by each common transport channel.

Table 26 - Parameters for Common Transport Channels

Transport Channel	Spectral Efficiency (bps/Hz)	Code Rate	Modulation Scheme	Transmission Mode	Message Size	
					bits	OFDM symbols
BCH	0.25	1/4	BPSK	Diversity	120	10
FCCH	0.25	1/4	BPSK	Diversity	variable	variable
"	0.5	1/2	BPSK	Diversity	variable	variable
"	1.0	1/2	QPSK	Diversity	variable	variable
"	2.0	1/2	16 QAM	Diversity	variable	variable
RACH	0.25	1/4	BPSK	Beam-Steering	96	8
"	0.5	1/2	BPSK	Beam-Steering	96, 192	4,8
"	1.0	1/2	QPSK	Beam-Steering	96, 192, 384	2, 4, 8
"	2.0	1/2	16 QAM	Beam-Steering	96, 192, 384, 768	1, 2, 4, 8

The FCCH message is variable in size and given in even number of OFDM symbols.

[0171] The FCH and RCH support all of the rates listed in Table 25. Table 27 lists the coding, modulation, and transmission parameters and the message sizes supported by the FCH and RCH.

Table 27 - Parameters for FCH and RCH

					PHY Frame Size		
					code bits	mod symbols	OFDM symbols
0.25 [A]	1/4	BPSK	72	72	144	288	6
0.5	1/2	BPSK	144	144	288	288	6
1.0	1/2	QPSK	288	288	576	288	6
1.5	3/4	QPSK	432	144	576	288	6
2.0	1/2	16 QAM	576	576	1152	288	6
2.5	5/8	16 QAM	720	432	1152	288	6
3.0	3/4	16 QAM	864	288	1152	288	6
3.5	7/12	64 QAM	1008	720	1728	288	6
4.0	2/3	64 QAM	1152	576	1728	288	6
4.5	3/4	64 QAM	1296	432	1728	288	6
5.0	5/6	64 QAM	1440	288	1728	288	6
5.5	11/16	256 QAM	1584	720	2304	288	6
6.0	3/4	256 QAM	1728	576	2304	288	6
6.5	13/16	256 QAM	1872	432	2304	288	6
7.0	7/8	256 QAM	2016	288	2304	288	6

Note A: each rate 1/2 code bit is repeated on two subbands to obtain an effective code rate of 1/4. The parity bits represent redundancy bits introduced by the coding and are used for error correction by the receiver.

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[0172] The PHY frame size in Table 27 indicates the number of code bits, modulation symbols, and OFDM symbols for each PHY frame. If 48 data subbands are used for data transmission, then each OFDM symbol includes 48 modulation symbols. For the diversity and beam-steering modes, one symbol stream is transmitted and the PHY frame size corresponds to the single rate employed for this symbol stream. For the spatial multiplexing mode, multiple symbol streams may be sent on multiple spatial channels, and the overall PHY frame size is determined by the sum of the PHY frame sizes for the individual spatial channels. The PHY frame size for each spatial channel is determined by the rate employed for that spatial channel.

[0173] As an example, suppose the MIMO channel is capable of supporting four spatial channels operating at spectral efficiencies of 0.5, 1.5, 4.5, and 5.5 bps/Hz. The four rates selected for the four spatial channels would then be as shown in Table 28.

Table 28 - Example Spatial Multiplexing Transmission

Spatial channel Index	Spectral Efficiency (bps/Hz)	Code Rate	Modulation Scheme	Payload (bits/ PHY frame)	PHY Frame Size		
					code bits	mod symbols	OFDM symbols
1	0.5	1/2	BPSK	144	288	288	6
2	1.5	3/4	QPSK	432	576	288	6
3	4.5	3/4	64 QAM	1296	1728	288	6
4	5.5	11/16	256 QAM	1584	2304	288	6

The overall PHY frame size is then 144 + 432 + 1296 + 1584 = 3456 information bits or 288+576+1728+2304=4896 code bits. Even though each of the four spatial channels supports a different number of payload bits, the overall PHY frame can be transmitted in 6 OFDM symbols (e.g., 24 μsec, assuming 4 μsec/OFDM symbol).

V. Physical Layer Processing

[0174] **FIG. 7** shows a block diagram of an embodiment of an access point 110x and two user terminals 120x and 120y within the MIMO WLAN system.

[0175] On the downlink, at access point 110x, a transmit (TX) data processor 710 receives traffic data (i.e., information bits) from a data source 708 and signaling and other information from a controller 730 and possibly a scheduler 734. These various types of data may be sent on different transport channels. TX data processor 710 "frames" the data (if necessary), scrambles the framed/unframed data, encodes the scrambled data, interleaves (i.e., reorders) the coded data, and maps the interleaved data into modulation symbols. For simplicity, a "data symbol" refers to a modulation symbol for traffic data, and a "pilot symbol" refers to a modulation symbol for pilot. The scrambling randomizes the data bits. The encoding increases the reliability of the data transmission. The interleaving provides time, frequency, and/or spatial diversity for the code bits. The scrambling, coding, and modulation may be performed based on control signals provided by controller 730 and are described in further detail below. TX data processor 710 provides a stream of modulation symbols for each spatial channel used for data transmission.

[0176] A TX spatial processor 720 receives one or more modulation symbol streams from TX data processor 710 and performs spatial processing on the modulation symbols to provide four streams of transmit symbols, one stream for each transmit antenna. The spatial processing is described in further detail below.

[0177] Each modulator (MOD) 722 receives and processes a respective transmit symbol stream to provide a corresponding stream of OFDM symbols. Each OFDM symbol stream is further processed to provide a corresponding downlink modulated signal. The four downlink modulated signals from modulator 722a through 722d are then transmitted from four antennas 724a through 724d, respectively.

[0178] At each user terminal 120, one or multiple antennas 752 receive the transmitted downlink modulated signals, and each receive antenna provides a received signal to a respective demodulator (DEMOD) 754. Each demodulator 754 performs processing complementary to that performed at modulator 722 and provides received symbols. A receive (RX) spatial processor 760 then performs spatial processing on the received symbols from all demodulators 754 to provide recovered symbols, which are estimates of the modulation symbols sent by the access point.

[0179] An RX data processor 770 receives and demultiplexes the recovered symbols into their respective transport channels. The recovered symbols for each transport channel may be symbol demapped, deinterleaved, decoded, and descrambled to provide decoded data for that transport channel. The decoded data for each transport channel may include recovered packet data, messages, signaling, and so on, which are provided to a data sink 772 for storage and/or

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a controller 780 for further processing.

[0180] The processing by access point 110 and terminal 120 for the downlink is described in further detail below. The processing for the uplink may be the same or different from the processing for the downlink.

[0181] For the downlink, at each active user terminal 120, RX spatial processor 760 further estimates the downlink to obtain channel state information (CSI). The CSI may include channel response estimates, received SNRs, and so on. RX data processor 770 may also provide the status of each packet/frame received on the downlink. A controller 780 receives the channel state information and the packet/frame status and determines the feedback information to be sent back to the access point. The feedback information is processed by a TX data processor 790 and a TX spatial processor 792 (if present), conditioned by one or more modulators 754, and transmitted via one or more antennas 752 back to the access point.

[0182] At access point 110, the transmitted uplink signal(s) are received by antennas 724, demodulated by demodulators 722, and processed by an RX spatial processor 740 and an RX data processor 742 in a complementary manner to that performed at the user terminal. The recovered feedback information is then provided to controller 730 and a scheduler 734.

[0183] Scheduler 734 uses the feedback information to perform a number of functions such as (1) selecting a set of user terminals for data transmission on the downlink and uplink, (2) selecting the transmission rate(s) and the transmission mode for each selected user terminal, and (3) assigning the available FCH/RCH resources to the selected terminals. Scheduler 734 and/or controller 730 further uses information (e.g., steering vectors) obtained from the uplink transmission for the processing of the downlink transmission, as described in further detail below.

[0184] A number of transmission modes are supported for data transmission on the downlink and uplink. The processing for each of these transmission modes is described in further detail below.

1. Diversity Mode - Transmit Processing

[0185] **FIG. 8A** shows a block diagram of an embodiment of a transmitter unit 800 capable of performing the transmit processing for the diversity mode. Transmitter unit 800 may be used for transmitter portion of the access point and the user terminal.

[0186] Within a TX data processor 710a, a framing unit 808 frames the data for each packet to be transmitted on the FCH or RCH. The framing need not be performed for the other transport channels. The framing may be performed as illustrated in FIG. 6 to generate one or more PHY frames for each user packet. A scrambler 810 then scrambles the framed/unframed data for each transport channel to randomize the data.

[0187] An encoder 812 receives and codes the scrambled data in accordance with a selected coding scheme to provide code bits. A repeat/puncture unit 814 then repeats or punctures (i.e., deletes) some of the code bits to obtain the desired code rate. In an embodiment, encoder 812 is a rate 1/2, constraint length 7, binary convolutional encoder. A code rate of 1/4 may be obtained by repeating each code bit once. Code rates greater than 1/2 may be obtained by deleting some of the code bits from encoder 812. A specific design for framing unit 808, scrambler 810, encoder 812, and repeat/puncture unit 814 is described below.

[0188] An interleaver 818 then interleaves (i.e., reorders) the code bits from unit 814 based on a selected interleaving scheme. In an embodiment, each group of 48 consecutive code bits to be transmitted on a given spatial channel is spread over the 48 data-carrying subbands (or simply, data subbands) to provide frequency diversity. The interleaving is described in further detail below.

[0189] A symbol mapping unit 820 then maps the interleaved data in accordance with a particular modulation scheme to provide modulation symbols. As shown in Table 26, BPSK, 4 QAM, or 16 QAM may be used for the diversity mode, depending on the selected rate. In the diversity mode, the same modulation scheme is used for all data subbands. The symbol mapping may be achieved by (1) grouping sets of B bits to form B-bit values, where $B \geq 1$, and (2) mapping each B-bit value to a point in a signal constellation corresponding to the selected modulation scheme. Each mapped signal point is a complex value and corresponds to a modulation symbol. Symbol mapping unit 820 provides a stream of modulation symbols to a TX diversity processor 720a.

[0190] In an embodiment, the diversity mode utilizes space-time transmit diversity (STTD) for dual transmit diversity on a per subband basis. STTD supports simultaneous transmission of independent symbol streams on two transmit antennas while maintaining orthogonality at the receiver.

[0191] The STTD scheme operates as follows. Suppose that two modulation symbols, denoted as s_1 and s_2, are to be transmitted on a given subband. The transmitter generates two vectors, $\underline{\mathbf{x}}_1 = [s_1 \; s_2]^T$ and $\underline{\mathbf{x}}_2 = [s_2^* \; -s_1^*]^T$, where "*" denotes the complex conjugate and "^{T}" denotes the transpose. Each vector includes two elements that are to be transmitted from two transmit antennas in one symbol period (i.e., vector $\underline{\mathbf{x}}_1$ is transmitted from two antennas in the first symbol period, and vector $\underline{\mathbf{x}}_2$ is transmitted from two antennas in the next symbol period).

[0192] If the receiver is equipped with a single receive antenna, then the received symbols may be expressed as:

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$$r_1 = h_1 s_1 + h_2 s_2 + n_1 \quad , \text{ and} \quad , \qquad \text{Eq (1)}$$

$$r_2 = h_1 s_2^* - h_2 s_1^* + n_2 \quad ,$$

where r_1 and r_2 are two symbols received in two consecutive symbol periods at the receiver;
h_1 and h_2 are the path gains from the two transmit antennas to the receive antenna for the subband under consideration, where the path gains are assumed to be constant over the subband and static over the 2-symbol period; and
n_1 and n_2 are the noise associated with the two received symbols r_1 and r_2, respectively.

[0193] The receiver may then derive estimates of the two transmitted symbols, s_1 and s_2 , as follows:

$$\hat{s}_1 = \frac{h_1^* r_1 - h_2 r_2^*}{|h_1|^2 + |h_2|^2} = s_1 + \frac{h_1^* n_1 - h_2 n_2^*}{|h_1|^2 + |h_2|^2} \quad , \text{ and} \qquad \text{Eq (2)}$$

$$\hat{s}_2 = \frac{h_2^* r_1 + h_1 r_2^*}{|h_1|^2 + |h_2|^2} = s_2 + \frac{h_2^* n_1 + h_1 n_2^*}{|h_1|^2 + |h_2|^2} \quad .$$

[0194] Alternatively, the transmitter may generate two vectors $\underline{x}_1 = [s_1 \quad -s_2^*]^T$ and $\underline{x}_2 = [s_2 \quad s_1^*]^T$ and transmit the two vectors sequentially in two symbol periods from two transmit antennas. The received symbols may then be expressed as:

$$r_1 = h_1 s_1 - h_2 s_2^* + n_1 \quad ,$$

and

$$r_2 = h_1 s_2 + h_2 s_1^* + n_2 \quad .$$

The receiver may then derive estimates of the two transmitted symbols as follows:

$$\hat{s}_1 = \frac{h_1^* r_1 + h_2 r_2^*}{|h_1|^2 + |h_2|^2} = s_1 + \frac{h_1^* n_1 + h_2 n_2}{|h_1|^2 + |h_2|^2} \quad ,$$

and

$$\hat{s}_2 = \frac{-h_2 r_1^* + h_1^* r_2}{|h_1|^2 + |h_2|^2} = s_2 + \frac{h_1^* n_2 - h_2 n_1}{|h_1|^2 + |h_2|^2} \quad .$$

[0195] The above description may be extended for a MIMO-OFDM system with two or more transmit antennas, N_R receive antennas, and multiple subbands. Two transmit antennas are used for any given subband. Suppose that two modulation symbols, denoted as $s_1(k)$ and $s_2(k)$, are to be transmitted on a given subband k. The transmitter generates two vectors $\underline{x}_1(k)=[s_1(k) \quad s_2(k)]^T$ and $\underline{x}_2(k) = [s_2^*(k) \quad -s_1^*(k)]^T$ or equivalently two symbol sets $\{x_i(k)\} = \{s_1(k) \quad s_2^*(k)\}$ and $\{x_j(k)\} = \{s_2(k) \quad -s_1^*(k)\}$. Each symbol set includes two elements that are to be transmitted sequentially in two symbol periods from a respective transmit antenna on subband k (i.e., symbol set $\{x_i(k)\}$ is transmitted on subband k from antenna i in two symbol periods, and symbol set $\{x_j(k)\}$ is transmitted on subband

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k from antenna j in the same 2-symbol period).

[0196] The vectors of received symbols at the receive antennas in the two symbol periods may be expressed as:

$$\underline{\mathbf{r}}_1(k) = \underline{\mathbf{h}}_i(k)s_1(k) + \underline{\mathbf{h}}_j(k)s_2(k) + \underline{\mathbf{n}}_1(k) \quad ,$$

and

$$\underline{\mathbf{r}}_2(k) = \underline{\mathbf{h}}_i(k)s_2^*(k) - \underline{\mathbf{h}}_j(k)s_1^*(k) + \underline{\mathbf{n}}_2(k) \quad ,$$

where $\underline{\mathbf{r}}_1(k)$ and $\underline{\mathbf{r}}_2(k)$ are two symbol vectors received in two consecutive symbol periods on subband k at the receiver, with each vector including N_R received symbols for N_R receive antennas;
$\underline{\mathbf{h}}_i(k)$ and $\underline{\mathbf{h}}_j(k)$ are the vectors of path gains from the two transmit antennas i and j to the N_R receive antennas for subband k, with each vector including the channel gains from the associated transmit antenna to each of the N_R receive antennas, where the path gains are assumed to be constant over the subband and static over the 2-symbol period; and
$\underline{\mathbf{n}}_1(k)$ and $\underline{\mathbf{n}}_2(k)$ are noise vectors associated with the two received vectors $\underline{\mathbf{r}}_1(k)$ and $\underline{\mathbf{r}}_2(k)$, respectively.

[0197] The receiver may then derive estimates of the two transmitted symbols, $s_1(k)$ and $s_2(k)$, as follows:

$$\hat{s}_1(k) = \frac{\hat{\underline{\mathbf{h}}}_i^H(k)\underline{\mathbf{r}}_1(k) - \underline{\mathbf{r}}_2^H(k)\hat{\underline{\mathbf{h}}}_j(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} = s_1(k) + \frac{\hat{\underline{\mathbf{h}}}_i^H(k)\underline{\mathbf{n}}_1(k) - \underline{\mathbf{n}}_2^H(k)\hat{\underline{\mathbf{h}}}_j(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} \quad ,$$

and

$$\hat{s}_2(k) = \frac{\hat{\underline{\mathbf{h}}}_j^H(k)\underline{\mathbf{r}}_1(k) + \underline{\mathbf{r}}_2^H(k)\hat{\underline{\mathbf{h}}}_i(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} = s_2(k) + \frac{\hat{\underline{\mathbf{h}}}_j^H(k)\underline{\mathbf{n}}_1(k) + \underline{\mathbf{n}}_2^H(k)\hat{\underline{\mathbf{h}}}_i(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} \quad .$$

[0198] Alternatively, the transmitter may generate two symbol sets $\{x_i(k)\} = \{s_1(k) \;\; s_2(k)\}$ and $\{x_j(k)\} = \{-s_2^*(k) \;\; s_1^*(k)\}$ and transmit these two symbol sets from two transmit antennas i and j. The vectors of received symbols may then be expressed as:

$$\underline{\mathbf{r}}_1(k) = \underline{\mathbf{h}}_i(k)s_1(k) - \underline{\mathbf{h}}_j(k)s_2^*(k) + \underline{\mathbf{n}}_1(k) \quad ,$$

and

$$\underline{\mathbf{r}}_2(k) = \underline{\mathbf{h}}_i(k)s_2(k) + \underline{\mathbf{h}}_j(k)s_1^*(k) + \underline{\mathbf{n}}_2(k) \quad .$$

The receiver may then derive estimates of the two transmitted symbols as follows:

$$\hat{s}_1(k) = \frac{\hat{\underline{\mathbf{h}}}_i^H(k)\underline{\mathbf{r}}_1(k) + \underline{\mathbf{r}}_2^H(k)\hat{\underline{\mathbf{h}}}_j(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} = s_1(k) + \frac{\hat{\underline{\mathbf{h}}}_i^H(k)\underline{\mathbf{n}}_1(k) + \underline{\mathbf{n}}_2^H(k)\hat{\underline{\mathbf{h}}}_j(k)}{\|\hat{\underline{\mathbf{h}}}_i(k)\|^2 + \|\hat{\underline{\mathbf{h}}}_j(k)\|^2} \quad ,$$

and

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$$\hat{s}_2(k) = \frac{\hat{\underline{h}}_i^H(k)\underline{r}_2(k) - \underline{r}_1^H(k)\hat{\underline{h}}_j(k)}{\|\hat{\underline{h}}_i(k)\|^2 + \|\hat{\underline{h}}_j(k)\|^2} = s_2(k) + \frac{\hat{\underline{h}}_i^H(k)\underline{n}_2(k) - \underline{n}_1^H(k)\hat{\underline{h}}_j(k)}{\|\hat{\underline{h}}_i(k)\|^2 + \|\hat{\underline{h}}_j(k)\|^2} \quad .$$

[0199] The STTD scheme is described by S.M. Alamouti in a paper entitled "A Simple Transmit Diversity Technique for Wireless Communications," IEEE Journal on Selected Areas in Communications, Vol. 16, No. 8, October 1998, pgs. 1451-1458. The STTD scheme is also described in commonly assigned U.S. Patent Application Serial No. 09/737,602, entitled "Method and System for Increased Bandwidth Efficiency in Multiple Input - Multiple Output Channels," filed January 5, 2001, and U.S. Patent Application Serial No. 10/179,439, entitled "Diversity Transmission Modes for MIMO OFDM Communication Systems," filed June 24, 2002.

[0200] The STTD scheme effectively transmits one modulation symbol per subband over two transmit antennas in each symbol period. However, the STTD scheme distributes the information in each modulation symbol over two successive OFDM symbols. Thus, the symbol recovery at the receiver is performed based on two consecutive received OFDM symbols.

[0201] The STTD scheme utilizes one pair of transmit antennas for each data subband. Since the access point includes four transmit antennas, each antenna may be selected for use for half of the 48 data subbands. Table 29 lists an exemplary subband-antenna assignment scheme for the STTD scheme.

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Table 29

Subband Indices	TX Ant	Bit Index	Subband Indices	TX Ant	Bit Index	Subband Indices	TX Ant	Bit Index	Subband Indices	TX Ant	Bit Index
-	-	-	-13	1,2	26	1	3,4	1	15	1,2	33
-26	1,2	0	-12	3,4	32	2	1,2	7	16	2,4	39
-25	3,4	6	-11	1,3	38	3	2,4	13	17	1,3	45
-24	1,3	12	-10	2,4	44	4	1,3	19	18	2,3	5
-23	2,4	18	-9	1,4	4	5	2,3	25	19	1,4	11
-22	1,4	24	-8	2,3	10	6	1,4	31	20	3,4	17
-21	1	P0	-7	2	P1	7	3	P2	21	4	P3
-20	2,3	30	-6	1,2	16	8	3,4	37	22	1,2	23
-19	1,2	36	-5	3,4	22	9	1,2	43	23	2,4	29
-18	3,4	42	-4	1,3	28	10	2,4	3	24	1,3	35
-17	1,3	2	-3	2,4	34	11	1,3	9	25	2,3	41
-16	2,4	8	-2	1,4	40	12	2,3	15	26	1,4	47
-15	1,4	14	-1	2,3	46	13	1,4	21	-	-	-
-14	2,3	20	0	-	-	14	3,4	27	-	-	-

[0202] As shown in Table 29, transmit antennas 1 and 2 are used for subbands with indices -26, -19, -13, and so on, transmit antennas 2 and 4 are used for subbands with indices -25, -18, -12, and so on, transmit antennas 1 and 3 are used for subbands with indices -24, -17, -11, *and* so on. There are six different antenna pairings with four transmit antennas. Each of the six antenna pairings is used for 8 data subbands, which are spaced approximately uniformly across the 48 data subbands. The antenna pairing to subband assignment is such that different antennas are used for adjacent subbands, which may provide greater frequency and spatial diversity. For example, antennas 1 and 2 are used for subband -26, and antennas 3 and 4 are used for subband -25.

[0203] The antenna-subband assignment in Table 29 is also such that all four transmit antennas are used for each code bit for the lowest rate of 1/4, which may maximize spatial diversity. For rate 1/4, each code bit is repeated and sent on two subbands (which is also referred to as dual subband repeat coding). The two subbands used for each code bit are mapped to different antenna pairs so that all four antennas are used to transmit that code bit. For example, bit indices 0 and 1 in Table 29 correspond to the same code bit for the diversity mode, where the bit with index 0 is transmitted from antennas 1 and 2 on subband -26 and the bit with index 1 is transmitted from antennas 3 and 4 on subband 1. As another example, bit indices 2 and 3 in Table 29 correspond to the same code bit, where the bit with index 2 is transmitted from antennas 1 and 3 in subband -17 and the bit with index 3 is transmitted from antennas 2 and 4 in subband 10.

[0204] The system may support other transmit diversity schemes, and this is within the scope of the invention. For example, the system may support a space-frequency transmit diversity (SFTD) that can achieve space and frequency diversity on a per-subband-pair basis. An exemplary SFTD scheme operates as follows. Suppose that two modulation symbols, denoted as $s(k)$ and $s(k+1)$, are generated and mapped to two adjacent subbands of an OFDM symbol. For SFTD, the transmitter would transmit symbols $s(k)$ and $s(k+1)$ from two antennas on subband k and would transmit symbols $s^*(k+1)$ and $-s^*(k)$ from the same two antennas on subband $k+1$. Adjacent subbands are used for the pair of modulation symbols because the channel response is assumed to be constant for the transmission of the two pairs of symbols. The processing at the receiver to recover the modulation symbols is the same as for the STTD scheme, except that the received symbols for two subbands instead of two OFDM symbol periods are processed.

[0205] **FIG. 8B** shows a block diagram of an embodiment of a TX diversity processor 720a capable of implementing the STTD scheme for the diversity mode.

[0206] Within TX diversity processor 720a, a demultiplexer 832 receives and demultiplexes the stream of modulation symbols $s(n)$ from TX data processor 710a into 48 substreams, denoted as $s_1(n)$ through $s_K(n)$, for the 48 data subbands. Each modulation symbol substream includes one modulation symbol for each symbol period, which corresponds to a symbol rate of $(T_{OFDM})^{-1}$, where T_{OFDM} is the duration of one OFDM symbol. Each modulation symbol substream is provided to a respective TX subband diversity processor 840.

[0207] Within each TX subband diversity processor 840, a demultiplexer 842 demultiplexes the modulation symbols for the subband into two symbol sequences, with each sequence having a symbol rate of $(2T_{OFDM})^{-1}$. A space-time encoder 850 receives the two modulation symbol sequences and, for each 2-symbol period, uses two symbols s_1 and s_2 in the two sequences to form two symbol sets $\{x_i\} = \{s_1 \quad s_2^*\}$ and $\{x_j\} = \{s_2 \quad -s_1^*\}$ for two transmit antennas. Each symbol set includes two symbols, one symbol from each of the two sequences. Symbol set $\{x_i\}$ is generated by providing symbol s_1 first and symbol s_2^* next, where s_1 is obtained via a switch 856a and s_2^* is obtained by taking the conjugate of s_2 with a unit 852a and delaying the conjugated symbol by one symbol period with a delay unit 854a. Similarly, symbol set $\{x_j\}$ is generated by providing symbol s_2 first and symbol $-s_1^*$ next, where s_2 is obtained via a switch 856b and $-s_1^*$ is obtained by taking the negative conjugate of s_1 with a unit 852b and delaying the negative conjugated symbol by one symbol period with a delay unit 854b. The two symbol sets $\{x_i\}$ and $\{x_j\}$ are to be transmitted from two antennas i and j assigned to the subband, as indicated in Table 29. Space-time encoder 850 provides the first symbol set $\{x_i\} = \{s_1 \quad s_2^*\}$ to a buffer/multiplexer 870 for the first transmit antenna i and the second symbol set $\{x_j\} = \{s_2 \quad -s_1^*\}$ to another buffer/multiplexer 870 for the second transmit antenna j. The two symbols provided by space-time encoder 850 for each symbol period are referred to as STTD symbols.

[0208] Buffers/multiplexers 870a through 870d are used to buffer and multiplex the STTD symbols from all diversity processors 840. Each buffer/multiplexer 870 receives pilot symbols and STTD symbols from the appropriate TX subband diversity processors 840, as determined by Table 29. For example, buffer/multiplexer 870a receives modulation symbols for subbands -26, -24, -22, -19, and so on (i.e., all subbands mapped to antenna 1), buffer/multiplexer 870b receives modulation symbols for subbands -26, -23, -20, -19, and so on (i.e., all subbands mapped to antenna 2), buffer/multiplexer 870c receives modulation symbols for subbands -25, -24, -20, -18, and so on (i.e., all subbands mapped to antenna 3), and buffer/multiplexer 870d receives modulation symbols for subbands -25, -23, -22, -18, and so on (i.e., all subbands mapped to antenna 4).

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[0209] Each buffer/multiplexer 870 then, for each symbol period, multiplexes four pilots, 24 STTD symbols, and 36 zeros for the four pilot subbands, 24 data subbands, and 36 unused subbands, respectively, to form a sequence of 64 transmit symbols for the 64 total subbands. Although there are a total of 48 data subbands, only 24 subbands are used for each transmit antenna for the diversity mode, and the effective total number of unused subbands for each antenna is thus 36 instead of 12. Each transmit symbol is a complex value (which may be zero for an unused subband) that is sent on one subband in one symbol period. Each buffer/multiplexer 870 provides a stream of transmit symbols $x_i(n)$ for one transmit antenna. Each transmit symbol stream comprises concatenated sequences of 64 transmit symbols, one sequence for each symbol period. Referring back to FIG. 8A, TX diversity processor 720a provides four transmit symbol streams, $x_1(n)$ through $x_4(n)$, to four OFDM modulators 722a through 722d.

[0210] **FIG. 8C** shows a block diagram of an embodiment of an OFDM modulator 722x, which may be used for each of OFDM modulators 722a through 722d in FIG. 8A. Within OFDM modulator 722x, an inverse fast Fourier transform (IFFT) unit 852 receives a stream of transmit symbol, $x_i(n)$, and converts each sequence of 64 transmit symbols into its time-domain representation (which is referred to as a transformed symbol) using a 64-point inverse fast Fourier transform. Each transformed symbol comprises 64 time-domain samples corresponding to the 64 total subbands.

[0211] For each transformed symbol, cyclic prefix generator 854 repeats a portion of the transformed symbol to form a corresponding OFDM symbol. As noted above, one of two different cyclic prefix lengths may be used. The cyclic prefix for the BCH is fixed and is 800 nsec. The cyclic prefix for all other transport channels is selectable (either 400 nsec or 800 nsec) and indicated by the Cyclic Prefix Duration field of the BCH message. For a system with a bandwidth of 20 MHz, a sample period of 50 nsec, and 64 subbands, each transformed symbol has a duration of 3.2 msec (or 64x50 nsec) and each OFDM symbol has a duration of either 3.6 msec or 4.0 msec depending on whether the 400 nsec or 800 nsec cyclic prefix is used for the OFDM symbol.

[0212] **FIG. 8D** illustrates an OFDM symbol. The OFDM symbol is composed of two parts: a cyclic prefix having a duration of 400 or 800 nsec (8 or 16 samples) and a transformed symbol with a duration of 3.2 μsec (64 samples). The cyclic prefix is a copy of the last 8 or 16 samples (i.e., a cyclic continuation) of the transformed symbol and is inserted in front of the transformed symbol. The cyclic prefix ensures that the OFDM symbol retains its orthogonal property in the presence of multipath delay spread, thereby improving performance against deleterious path effects such as multipath and channel dispersion caused by frequency selective fading.

[0213] Cyclic prefix generator 854 provides a stream of OFDM symbols to a transmitter (TMTR) 856. Transmitter 856 converts the OFDM symbol stream into one or more analog signals, and further amplifies, filters, and frequency upconverts the analog signals to generate a modulated signal suitable for transmission from an associated antenna.

[0214] The baseband waveform for an OFDM symbol may be expressed as:

$$x_n(t) = \sum_{k=-N_{ST}/2, k\neq 0}^{N_{ST}/2} c_n(k)\Psi_n(k,t) \quad , \qquad \text{Eq (3)}$$

where n denotes the symbol period (i.e., the OFDM symbol index);
k denotes the subband index;
N_{ST} is the number of pilot and data subbands;
$c_n(k)$ denotes the symbol transmitted on subband k of symbol period n; and

$$\Psi_n(k,t) = \begin{cases} e^{j2\pi k\Delta f(t-T_{CP}-nT_S)} & , \text{ for } nT_S \le t \le (n+1)T_S \\ 0 & , \text{ otherwise} \end{cases} \quad , \qquad \text{Eq (4)}$$

where T_{CP} is the cyclic prefix duration;
T_S is the OFDM symbol duration; and
Δf is the bandwidth of each subband.

2. Spatial Multiplexing Mode - Transmit Processing

[0215] **FIG. 9A** shows a block diagram of a transmitter unit 900 capable of performing the transmit processing for the spatial multiplexing mode. Transmitter unit 900 is another embodiment of the transmitter portion of the access point and the user terminal. For the spatial multiplexing mode, again assuming that four transmit antennas and four receive antennas are available, data may be transmitted on up to four spatial channels. A different rate may be used for each

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spatial channel depending on its transmission capacity. Each rate is associated with a particular code rate and modulation scheme, as shown in Table 25. In the following description it is assumed that N_E spatial channels are selected for use for data transmission, where $N_E \leq N_S \leq \min\{N_T, N_R\}$.

[0216] Within a TX data processor 710b, framing unit 808 frames the data for each FCH/RCH packet to generate one or more PHY frames for the packet. Each PHY frame includes the number of data bits that may be transmitted in all N_E spatial channels within 6 OFDM symbols. Scrambler 810 scrambles the data for each transport channel. Encoder 812 receives and codes the scrambled data in accordance with a selected coding scheme to provide code bits. In an embodiment, a common coding scheme is used to code the data for all N_E spatial channels, and different code rates for different spatial channels are obtained by puncturing the code bits with different puncturing patterns. Puncture unit 814 thus punctures the code bits to obtain the desired code rate for each spatial channel. The puncturing for the spatial multiplexing mode is described in further detail below.

[0217] A demultiplexer 816 receives and demultiplexes the code bits from puncture unit 814 to provide N_E code bit streams for the N_E spatial channels selected for use. Each code bit stream is provided to a respective interleaver 818, which interleaves the code bits in the stream across the 48 data subbands. The coding and interleaving for the spatial multiplexing mode are described in further detail below. The interleaved data from each interleaver 818 is provided to a respective symbol mapping unit 820.

[0218] In the spatial multiplexing mode, up to four different rates may be used for the four spatial channels, depending on the received SNRs achieved for these spatial channels. Each rate is associated with a particular modulation scheme, as shown in Table 25. Each symbol mapping unit 820 maps the interleaved data in accordance with a particular modulation scheme selected for the associated spatial channel to provide modulation symbols. If all four spatial channels are selected for use, then symbol mapping units 820a through 820d provide four streams of modulation symbols for the four spatial channels to a TX spatial processor 720b.

[0219] TX spatial processor 720b performs spatial processing for the spatial multiplexing mode. For simplicity, the following description assumes that four transmit antennas, four receive antennas, and 48 data subbands are used for data transmission. The data subband indices are given by the set $\boldsymbol{K}$, where $K = \pm \{1, ..., 6, 8 ..., 20, 22, ... 26\}$ for the OFDM subband structure described above.

[0220] The model for a MIMO-OFDM system may be expressed as:

$$\underline{\mathbf{r}}(k) = \underline{\mathbf{H}}(k)\underline{\mathbf{x}}(k) + \underline{\mathbf{n}}(k) \quad , \text{for } k \in K , \qquad \text{Eq (5)}$$

where $\underline{\mathbf{r}}(k)$ is a "receive" vector with four entries for the symbols received via the four receive antennas for subband k (i.e., $\underline{\mathbf{r}}(k) = [r_1(k)\ r_2(k)\ r_3(k)\ r_4(k)]^T$);

$\underline{\mathbf{x}}(k)$ is a "transmit" vector with four entries for the symbols transmitted from the four transmit antennas for subband k (i.e., $\underline{\mathbf{x}}(k) = [x_1(k)\ x_2(k)\ x_3(k)\ x_4(k)]^T$);

$\underline{\mathbf{H}}(k)$ is an $(N_R \times N_T)$ channel response matrix for subband k; and

$\underline{\mathbf{n}}(k)$ is a vector of additive white Gaussian noise (AWGN) for subband k.

The noise vector $\underline{\mathbf{n}}(k)$ is assumed to have components with zero mean and a covariance matrix of $\Lambda_n = \sigma^2\underline{\mathbf{I}}$, where $\underline{\mathbf{I}}$ is the identity matrix and σ^2 is the noise variance.

[0221] The channel response matrix $\underline{\mathbf{H}}(k)$ for subband k may be expressed as:

$$\underline{\mathbf{H}}(k) = \begin{bmatrix} h_{1,1}(k) & h_{1,2}(k) & h_{1,3}(k) & h_{1,4}(k) \\ h_{2,1}(k) & h_{2,2}(k) & h_{2,3}(k) & h_{2,4}(k) \\ h_{3,1}(k) & h_{3,2}(k) & h_{3,3}(k) & h_{3,4}(k) \\ h_{4,1}(k) & h_{4,2}(k) & h_{4,3}(k) & h_{4,4}(k) \end{bmatrix} , \text{ for } k \in K , \qquad \text{Eq (6)}$$

where entry $h_{ij}(k)$, for $i \in \{1, 2, 3, 4\}$ and $j \in \{1, 2, 3, 4\}$, is the coupling (i.e., complex gain) between transmit antenna i and receive antenna j for subband k. For simplicity, it is assumed that the channel response matrices $\underline{\mathbf{H}}(k)$, for $k \in K$, are known or can be ascertained by both the transmitter and receiver.

[0222] The channel response matrix $\underline{\mathbf{H}}(k)$ for each subband may be "diagonalized" to obtain the N_S eigenmodes for that subband. This can be achieved by performing eigenvalue decomposition on the correlation matrix of $\underline{\mathbf{H}}(k)$, which is $\underline{\mathbf{R}}(k) = \underline{\mathbf{H}}^H(k)\underline{\mathbf{H}}(k)$, where $\underline{\mathbf{H}}^H(k)$ denotes the conjugate transpose of $\underline{\mathbf{H}}(k)$. The eigenvalue decomposition of the correlation matrix $\underline{\mathbf{R}}(k)$ may be expressed as:

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$$\underline{\mathbf{R}}(k) = \underline{\mathbf{V}}(k)\underline{\mathbf{D}}(k)\underline{\mathbf{V}}^H(k) \quad , \text{for } k \in K , \qquad \text{Eq (7)}$$

where $\underline{\mathbf{V}}(k)$ is an $(N_T \times N_T)$ unitary matrix whose columns are eigenvectors of $\underline{\mathbf{R}}(k)$ (i.e., $\underline{\mathbf{V}}(k)=[\underline{\mathbf{v}}_1(k)\ \underline{\mathbf{v}}_2(k)\ \underline{\mathbf{v}}_3(k)\ \underline{\mathbf{v}}_4(k)]$, where each $\underline{\mathbf{v}}_i(k)$ is an eigenvector for one eigenmode); and
$\underline{\mathbf{D}}(k)$ is an $(N_T \times N_T)$ diagonal matrix of eigenvalues of $\underline{\mathbf{R}}(k)$.
A unitary matrix is characterized by the property $\underline{\mathbf{M}}^H\underline{\mathbf{M}} = \underline{\mathbf{I}}$. Eigenvectors $\underline{\mathbf{v}}_i(k)$, for $i \in \{1, 2, 3, 4\}$, are also referred to as transmit steering vectors for each of the spatial channels.

[0223] The channel response matrix $\underline{\mathbf{H}}(k)$ may also be diagonalized using singular value decomposition, which may be expressed as:

$$\underline{\mathbf{H}}(k) = \underline{\mathbf{U}}(k)\underline{\Sigma}(k)\underline{\mathbf{V}}^H(k) \quad , \text{for } k \in K , \qquad \text{Eq (8)}$$

where $\underline{\mathbf{V}}(k)$ is a matrix whose columns are right eigenvectors of $\underline{\mathbf{H}}(k)$;
$\underline{\Sigma}(k)$ is a diagonal matrix containing singular values of $\underline{\mathbf{H}}(k)$, which are positive square roots of the diagonal elements of $\underline{\mathbf{D}}(k)$, the eigenvalues of $\underline{\mathbf{R}}(k)$; and
$\underline{\mathbf{U}}(k)$ is a matrix whose columns are left eigenvectors of $\underline{\mathbf{H}}(k)$.
Singular value decomposition is described by Gilbert Strang in a book entitled "Linear Algebra and Its Applications," Second Edition, Academic Press, 1980. As shown in equations (7) and (8), the columns of the matrix $\underline{\mathbf{V}}(k)$ are eigenvectors of $\underline{\mathbf{R}}(k)$ as well as right eigenvectors of $\underline{\mathbf{H}}(k)$. The columns of the matrix $\underline{\mathbf{U}}(k)$ are eigenvectors of $\underline{\mathbf{H}}(k)\underline{\mathbf{H}}^H(k)$ as well as left eigenvectors of $\underline{\mathbf{H}}(k)$.

[0224] The diagonal matrix $\underline{\mathbf{D}}(k)$ for each subband contains non-negative real values along the diagonal and zeros everywhere else. The eigenvalues of $\underline{\mathbf{R}}(k)$ are denoted as $\{\lambda_1(k), \lambda_2(k), \lambda_3(k), \lambda_4(k)\}$ or $\{\lambda_i(k)\}$ for $i \in \{1,2,3,4\}$.

[0225] The eigenvalue decomposition may be performed independently for the channel response matrix $\underline{\mathbf{H}}(k)$ for each of the 48 data subbands to determine the four eigenmodes for that subband (assuming that each matrix $\underline{\mathbf{H}}(k)$ is full rank). The four eigenvalues for each diagonal matrix $\underline{\mathbf{D}}(k)$ may be ordered such that $\{\lambda_1(k) \geq \lambda_2(k) \geq \lambda_3(k) \geq \lambda_4(k)\}$, where $\lambda_1(k)$ is the largest eigenvalue and $\lambda_4(k)$ is the smallest eigenvalue for subband k. When the eigenvalues for each diagonal matrix $\underline{\mathbf{D}}(k)$ are ordered, the eigenvectors (or columns) of the associated matrix $\underline{\mathbf{V}}(k)$ are also ordered correspondingly.

[0226] A "wideband" eigenmode may be defined as the set of same-order eigenmodes of all subbands after the ordering (i.e., wideband eigenmode m includes eigenmodes m of all subbands). Each wideband eigenmode is associated with a respective set of eigenvectors for all of the subbands. The "principal" wideband eigenmode is the one associated with the largest singular value in each of the matrices $\underline{\Sigma}(k)$ after the ordering.

[0227] A vector $\underline{\mathbf{d}}^m$ may then be formed to include the m-th rank eigenvalue for all 48 data subbands. This vector $\underline{\mathbf{d}}^m$ may be expressed as:

$$\underline{\mathbf{d}}^m = [\lambda_m(-26) \ \ldots\ \lambda_m(-22) \ \ldots \lambda_m(22) \ \ldots\ \lambda_m(26)] \ , \text{ for } m = \{1, 2, 3, 4\} . \qquad \text{Eq (9)}$$

The vector $\underline{\mathbf{d}}^1$ includes the eigenvalues for the best or principal wideband eigenmode. For a MIMO-OFDM system with four transmit antennas and four receive antennas (i.e., a 4 × 4 system), there are up four wideband eigenmodes.

[0228] If the noise variance σ^2 at the receiver is constant across the operating band and known to the transmitter, then the received SNR for each subband of each wideband eigenmode may be determined by dividing the eigenvalue $\lambda_m(k)$ by the noise variance σ^2. For simplicity, the noise variance can be assumed to be equal to one (i.e., $\sigma^2 = 1$).

[0229] For the spatial multiplexing mode, the total transmit power P_{total} available to the transmitter may be distributed to the wideband eigenmodes based on various power allocation schemes. In one scheme, the total transmit power P_{total} is distributed uniformly to all four wideband eigenmodes such that $P_m = P_{total}/4$, where P_m is the transmit power allocated to wideband eigenmode m. In another scheme, the total transmit power P_{total} is distributed to the four wideband eigenmodes using a water-filling procedure.

[0230] The water-filling procedure distributes power such that the wideband eigenmodes with higher power gains receive greater fractions of the total transmit power. The amount of transmit power allocated to a given wideband eigenmode is determined by its received SNR, which in turn is dependent on the power gains (or eigenvalues) for all of the subbands of that wideband eigenmode. The water-filling procedure may allocate zero transmit power to wideband eigenmodes with sufficiently poor received SNRs. The water-filling procedure receives $\underline{\beta}=\{\beta_1, \beta_2, \beta_3, \beta_4\}$ for the four wideband eigenmodes, where β_m is a normalization factor for wideband eigenmode m and may be expressed as:

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$$\beta_m = \frac{1}{\sum_{k \in K} \lambda_m^{-1}(k)} \text{ , for } m = \{1, 2, 3, 4\} . \qquad \text{Eq (10)}$$

The normalization factor β_m keeps the transmit power allocated to wideband eigenmode m invariant after channel inversion is applied, as described below. As shown in equation (10), the normalization factor β_m can be derived based on the eigenvalues in the vector $\underline{d}^m$ and with the assumption of the noise variance being equal to one (i.e., $\sigma^2 = 1$).

[0231] The water-filling procedure then determines the fraction α_m of the total transmit power to allocate to each wideband eigenmode based on the set $\underline{\beta}$ such that spectral efficiency or some other criterion is optimized. The transmit power allocated to wideband eigenmode m by the water-filling procedure may be expressed as:

$$P_m = \alpha_m P_{total} \text{ , for } m = \{1, 2, 3, 4\} . \qquad \text{Eq (11)}$$

The power allocations for the four wideband eigenmodes may be given by $\underline{\alpha} = \{\alpha_1, \alpha_2, \alpha_3, \alpha_4\}$, where $\sum_{m=1}^{4} \alpha_m = 1$ and $\sum_{m=1}^{4} P_m = P_{total}$. The spatial multiplexing mode may be selected for use if more than one value in set $\underline{\alpha}$ is non-zero.

[0232] The procedure for performing water-filling is known in the art and not described herein. One reference that describes water-filling is "Information Theory and Reliable Communication," by Robert G. Gallager, John Wiley and Sons, 1968, which is incorporated herein by reference.

[0233] For the spatial multiplexing mode, the rate for each spatial channel or wideband eigenmode may be selected based on the received SNR achieved by that spatial channel/wideband eigenmode with its allocated transmit power of P_m. For simplicity, the following description assumes data transmission on the wideband eigenmodes. The received SNR for each wideband eigenmode may be expressed as:

$$\gamma_m = \frac{P_m \beta_m}{\sigma^2} \text{ , for } m = \{1, 2, 3, 4\} . \qquad \text{Eq (12)}$$

In one embodiment, the rate for each wideband eigenmode is determined based on a table that includes the rates supported by the system and a range of SNRs for each rate. This table may be obtained by computer simulation, empirical measurements, and so on. The particular rate to use for each wideband eigenmode is the rate in the table with a range of SNRs covering the received SNR for the wideband eigenmode. In another embodiment, the rate for each wideband eigenmode is selected based on (1) the received SNR for the wideband eigenmode, (2) an SNR offset used to account for estimation error, variability in the MIMO channel, and other factors, and (3) a table of supported rates and their required SNRs. For this embodiment, an average received SNR for each wideband eigenmode is first computed as described above or as an average of the received SNRs (in units of dBs) for all of the subbands of the wideband eigenmode. In any case, an operating SNR is next computed as the sum of the received SNR and the SNR offset (where both are given in units of dBs). The operating SNR is then compared against the required SNR for each of the rates supported by the system. The highest rate in the table with a required SNR that is less than or equal to the operating SNR is then selected for the wideband eigenmode. The rate for the transmit diversity mode and the beam-steering mode may also be determined in similar manner.

[0234] The transmit power P_m allocated for each wideband eigenmode may be distributed across the 48 data subbands of that wideband eigenmode such that the received SNRs for all subbands are approximately equal. This non-uniform allocation of power across the subbands is referred to as channel inversion. The transmit power $P_m(k)$ allocated to each subband may be expressed as:

$$P_m(k) = \frac{\beta_m P_m}{\lambda_m(k)} \text{ , for } k \in K \text{ and } m = \{1, 2, 3, 4\} , \qquad \text{Eq (13)}$$

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where β_m is given in equation (10).

[0235] As shown in equation (13), the transmit power P_m is distributed non-uniformly across the data subbands based on their channel power gains, which is given by the eigenvalues $\lambda_m(k)$, for $k \in K$. The power distribution is such that approximately equal received SNRs are achieved at the receiver for all data subbands of each wideband eigenmode. This channel inversion is performed independently for each of the four wideband eigenmodes. The channel inversion per wideband eigenmode is described in further detail in commonly assigned U.S. Patent Application Serial No. 10/229,209, entitled "Coded MIMO Systems with Selective Channel Inversion Applied Per Eigenmode," filed August 27, 2002.

[0236] The channel inversion may be performed in various manners. For full channel inversion, all data subbands are used for data transmission if a wideband eigenmode is selected for use. For selective channel inversion, all or a subset of the available data subbands may be selected for use for each wideband eigenmode. The selective channel inversion discards poor subbands with received SNR below a particular threshold and performs channel inversion on only the selected subbands. Selective channel inversion for each wideband eigenmode is also described in commonly assigned U.S. Patent Application Serial No. 10/229,209, entitled "Coded MIMO Systems with Selective Channel Inversion Applied Per Eigenmode," filed August 27, 2002. For simplicity, the following description assumes that full channel inversion is performed for each wideband eigenmode selected for use.

[0237] The gain to use for each subband of each wideband eigenmode may be determined based on the transmit power $P_m(k)$ allocated to that subband. The gain $g_m(k)$ for each data subband may be expressed as:

$$g_m(k) = \sqrt{P_m(k)} \ , \text{ for } k \in K \text{ and } m = \{1, 2, 3, 4\} . \qquad \text{Eq (14)}$$

A diagonal gain matrix $\underline{\mathbf{G}}(k)$ may be defined for each subband. This matrix $\underline{\mathbf{G}}(k)$ includes the gains for the four eigenmodes for subband k along the diagonal, and may be expressed as: $\underline{\mathbf{G}}(k) = \text{diag}[g_1(k), g_2(k), g_3(k), g_4(k)]$.

[0238] For the spatial multiplexing mode, the transmit vector $\mathbf{x}(k)$ for each data subband may be expressed as:

$$\underline{\mathbf{x}}(k) = \underline{\mathbf{V}}(k)\underline{\mathbf{G}}(k)\underline{\mathbf{s}}(k) \ , \text{for } k \in K , \qquad \text{Eq (15)}$$

where

$$\underline{\mathbf{s}}(k) = [s_1(k) \ s_2(k) \ s_3(k) \ s_4(k)]^T ,$$

and

$$\underline{\mathbf{x}}(k) = [x_1(k) \ x_2(k) \ x_3(k) \ x_4(k)]^T .$$

The vector $\underline{\mathbf{s}}(k)$ includes four modulation symbols to be transmitted on the four eigenmodes for subband k, and the vector $\underline{\mathbf{x}}(k)$ includes four transmit symbols to be transmitted from the four antennas for subband k. For simplicity, equation (15) does not include the correction factors used to account for differences between the transmit/receive chains at the access point and the user terminal, which are described in detail below.

[0239] **FIG. 9B** shows a block diagram of an embodiment of TX spatial processor 720b capable of performing spatial processing for the spatial multiplexing mode. For simplicity, the following description assumes that all four wideband eigenmodes are selected for use. However, less than four wideband eigenmodes may also be selected for use.

[0240] Within processor 720b, a demultiplexer 932 receives the four modulation symbol streams (denoted as $s_1(n)$ through $s_4(n)$) to be transmitted on the four wideband eigenmodes, demultiplexes each stream into 48 substreams for the 48 data subbands, and provides four modulation symbol substreams for each data subband to a respective TX subband spatial processor 940. Each processor 940 performs the processing shown in equation (15) for one subband.

[0241] Within each TX subband spatial processor 940, the four modulation symbol substreams (denoted as $s_1(k)$ through $s_4(k)$) are provided to four multipliers 942a through 942d, which also receive the gains $g_1(k)$, $g_2(k)$, $g_3(k)$, and $g_4(k)$ for the four eigenmodes of the associated subband. Each gain $g_m(k)$ may be determined based on the transmit power $P_m(k)$ allocated to that subband/eigenmode, as shown in equation (14). Each multiplier 942 scales its modulation

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symbols with its gain $g_m(k)$ to provide scaled modulation symbols. Multipliers 942a through 942d provide four scaled modulation symbol substreams to four beam-formers 950a through 950d, respectively.

[0242] Each beam-former 950 performs beam-forming to transmit one symbol substream on one eigenmode of one subband. Each beam-former 950 receives one symbol substream $s_m(k)$ and one eigenvector $\underline{\mathbf{v}}_m(k)$ for the associated eigenmode. In particular, beam-former 950a receives eigenvector $\underline{\mathbf{v}}_1(k)$ for the first eigenmode, beam-former 950b receives eigenvector $\underline{\mathbf{v}}_2(k)$ for the second eigenmode, and so on. The beam-forming is performed using the eigenvector for the associated eigenmode.

[0243] Within each beam-former 950, the scaled modulation symbols are provided to four multipliers 952a through 952d, which also receive four elements, $v_{m,1}(k)$, $v_{m,2}(k)$, $v_{m,3}(k)$, and $v_{m,4}(k)$, of eigenvector $\underline{\mathbf{v}}_m(k)$ for the associated eigenmode. Each multiplier 952 then multiplies the scaled modulation symbols with its eigenvector value $v_{m,j}(k)$ to provide "beam-formed" symbols. Multipliers 952a through 952d provide four beam-formed symbol substreams (which are to be transmitted from four antennas) to summers 960a through 960d, respectively.

[0244] Each summer 960 receives and sums four beam-formed symbols for the four eigenmodes for each symbol period to provide a preconditioned symbol for an associated transmit antenna. Summers 960a through 960d provide four substreams of preconditioned symbols for four transmit antennas to buffers/multiplexers 970a through 970d, respectively.

[0245] Each buffer/multiplexer 970 receives pilot symbols and the preconditioned symbols from TX subband spatial processors 940a through 940k for the 48 data subbands. Each buffer/multiplexer 970 then, for each symbol period, multiplexes 4 pilot symbols, 48 preconditioned symbols, and 12 zeros for 4 pilot subbands, 48 data subbands, and 12 unused subbands, respectively, to form a sequence of 64 transmit symbols for that symbol period. Each buffer/multiplexer 970 provides a stream of transmit symbols $x_j(n)$ for one transmit antenna, where the transmit symbol stream comprises concatenated sequences of 64 transmit symbols. The transmit symbols can be scaled with correction factors to account for differences between the transmit/receive chains at the access point and the user terminal, as described below. The subsequent OFDM modulation for each transmit symbol stream is described above.

[0246] Parallel symbol streams may also be transmitted from the four transmit antennas without spatial processing at the access point using the non-steered spatial multiplexing mode. For this mode, the channel inversion process and beam-forming by beam-former 950 may be omitted. Each modulation symbol stream is further OFDM processed and transmitted from a respective transmit antenna.

[0247] The non-steered spatial multiplexing mode may be used for various situations such as if the transmitter is unable to perform the spatial processing necessary to support beam-steering based on eigenmode decomposition. This may be because the transmitter has not performed calibration procedures, is unable to generate a sufficiently good estimate of the channel, or does not have calibration and eigenmode processing capabilities at all. For the non-steered spatial multiplexing mode, spatial multiplexing is still used to increase the transmission capacity, but the spatial processing to separate out the individual symbol streams is performed by the receiver.

[0248] For the non-steered spatial multiplexing mode, the receiver performs the spatial processing to recover the transmitted symbol streams. In particular, a user terminal may implement a channel correlation matrix inversion (CCMI) technique, a minimum mean square error (MMSE) technique, a successive interference cancellation receiver processing technique, or some other receiver spatial processing technique. These techniques are described in detail in commonly assigned U.S. Patent Application Serial No. 09/993,087, entitled "Multiple-Access Multiple-Input Multiple-Output (MIMO) Communication System," filed November 6, 2001. The non-steered spatial multiplexing mode may be used for both downlink and uplink transmissions.

[0249] The multi-user spatial multiplexing mode supports data transmission to multiple user terminals simultaneously on the downlink based on the "spatial signatures" of the user terminals. The spatial signature for a user terminal is given by a channel response vector (for each subband) between the access point antennas and each user terminal antenna. The access point may obtain the spatial signatures, for example, based on the steered reference transmitted by the user terminals. The access point may process the spatial signatures for user terminals desiring data transmission to (1) select a set of user terminals for simultaneous data transmission on the downlink and (2) derive steering vectors for each of the independent data streams to be transmitted to the selected user terminals.

[0250] The steering vectors for the multi-user spatial multiplexing mode may be derived in various manners. Two exemplary schemes are described below. For simplicity, the following description is for one subband and assumes that each user terminal is equipped with a single antenna.

[0251] In a first scheme, the access point obtains the steering vectors using channel inversion. The access point may select N_{ap} single-antenna user terminals for simultaneous transmission on the downlink. The access point obtains an $1 \times N_{ap}$ channel response row vector for each selected user terminal and forms an $N_{ap} \times N_{ap}$ channel response matrix $\underline{\mathbf{H}}_{mu}$ with the N_{ap} row vectors for the N_{ap} user terminals. The access point then obtains a matrix $\underline{\mathbf{H}}_{steer}$ of N_{ap} steering vectors for the N_{ap} selected user terminals as $\underline{\mathbf{H}}_{steer} = \underline{\mathbf{H}}_{mu}^{-1}$. The access point can also transmit a steered reference

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to each selected user terminal. Each user terminal processes its steered reference to estimate the channel gain and phase and coherently demodulates received symbols for its single antenna with the channel gain and phase estimates to obtain recovered symbols.

[0252] In a second scheme, the access point precodes N_{ap} symbol streams to be sent to N_{ap} user terminals such that these symbol streams experience little cross-talk at the user terminals. The access point can form the channel response matrix $\underline{H}_{mu}$ for the N_{ap} selected user terminals and perform QR factorization on $\underline{H}_{mu}$ such that $\underline{H}_{mu} = \underline{F}_{tri}\underline{Q}_{mu}$, where $\underline{T}_{tri}$ is a lower left triangular matrix $\underline{T}_{tri}$ and $\underline{Q}_{mu}$ is a unitary matrix. The access point then precodes the N_{ap} data symbol streams with the matrix $\underline{T}_{tri}$ to obtain N_{ap} precoded symbol streams $\underline{a}$, and further processes the precoded symbol streams with the unitary matrix $\underline{Q}_{mu}$ to obtain the N_{ap} transmit symbol streams for transmission to the N_{ap} user terminals. Again, the access point can also transmit a steered reference to each user terminal. Each user terminal uses the steered reference to coherently demodulate its received symbols to obtain recovered symbols.

[0253] For the uplink in the multi-user spatial multiplexing mode, the access point can recover N_{ap} symbol streams transmitted simultaneously by N_{ap} user terminals using MMSE receiver processing, successive interference cancellation, or some other receiver processing technique. The access point can estimate the uplink channel response for each user terminal and use the channel response estimate for receiver spatial processing and for scheduling uplink transmissions. Each single-antenna user terminal can transmit an orthogonal pilot on the uplink. The uplink pilots from the N_{ap} user terminals can be orthogonal in time and/or frequency. Time orthogonality can be achieved by having each user terminal covers its uplink pilot with an orthogonal sequence assigned to the user terminal. Frequency orthogonality can be achieved by having each user terminal transmits its uplink pilot on a different set of subbands. The uplink transmissions from the user terminals should be approximately time-aligned at the access point (e.g., time-aligned to within the cyclic prefix).

3. Beam-Steering Mode - Transmit Processing

[0254] **FIG. 10A** shows a block diagram of a transmitter unit 1000 capable of performing the transmit processing for the beam-steering mode. Transmitter unit 1000 is yet another embodiment of the transmitter portion of the access point and the user terminal.

[0255] Within a TX data processor 710c, framing unit 808 frames the data for each FCH/RCH packet to generate one or more PHY frames for the packet. Scrambler 810 then scrambles the data for each transport channel. Encoder 812 next codes the framed data in accordance with a selected coding scheme to provide code bits. Puncture unit 814 then punctures the code bits to obtain the desired code rate for the wideband eigenmode used for data transmission. The code bits from puncture unit 818 are interleaved across all data subbands. Symbol mapping unit 820 then maps the interleaved data in accordance with a selected modulation scheme to provide modulation symbols. A TX spatial processor 720c then performs transmit processing on the modulation symbols for the beam-steering mode.

[0256] The beam-steering mode may be used to transmit data on one spatial channel or wideband eigenmode - typically the one associated with the largest eigenvalues for all of the data subbands. The beam-steering mode may be selected if the transmit power allocation to the wideband eigenmodes results in only one entry in the set $\underline{\alpha}$ being non-zero. Whereas the spatial multiplexing mode performs beam-forming for each of the selected eigenmodes of each subband based on its eigenvector, the beam-steering mode performs beam-steering based on a "normalized" eigenvector for the principal eigenmode of each subband to transmit data on that single eigenmode.

[0257] The four elements of each eigenvector $\underline{v}_1(k)$, for $k \in K$, for the principal eigenmode may have different magnitudes. The four preconditioned symbols obtained based on the four elements of eigenvector $\underline{v}_1(k)$ for each subband may then have different magnitudes. Consequently, the four per-antenna transmit vectors, each of which includes the preconditioned symbols for all data subbands for a given transmit antenna, may have different magnitudes. If the transmit power for each transmit antenna is limited (e.g., because of limitations of the power amplifiers), then the beam-forming technique may not fully use the total power available for each antenna.

[0258] The beam-steering mode uses only the phase information from eigenvectors $\underline{v}_1(k)$, for $k \in K$, for the principal eigenmode and normalizes each eigenvector such that all four elements in the eigenvector have equal magnitudes. The normalized eigenvector $\underline{\tilde{v}}(k)$ for subband k may be expressed as:

$$\underline{\tilde{v}}(k) = [Ae^{j\theta_1(k)} \; Ae^{j\theta_2(k)} \; Ae^{j\theta_3(k)} \; Ae^{j\theta_4(k)}]^T , \qquad \text{Eq (16)}$$

where A is a constant (e.g., A = 1); and
$\theta_i(k)$ is the phase for subband k of transmit antenna i, which is given as:

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$$\theta_i(k) = \angle v_{1,i}(k) = \tan^{-1}\left(\frac{\mathrm{Im}\{v_{1,i}(k)\}}{\mathrm{Re}\{v_{1,i}(k)\}}\right) . \qquad \text{Eq (17)}$$

As shown in equation (17), the phase of each element in the vector $\underline{\tilde{v}}(k)$ is obtained from the corresponding element of eigenvector $\underline{v}_1(k)$ (i.e., $\theta_i(k)$ is obtained from $v_{1,i}(k)$, where $\underline{v}_1(k)=[v_{1,1}(k)\ v_{1,2}(k)\ v_{1,3}(k)\ v_{1,4}(k)]^T$).

[0259] Channel inversion may also be performed for the beam-steering mode so that a common rate can be used for all data subbands. The transmit power $\tilde{P}_1(k)$ allocated to each data subband for the beam-steering mode may be expressed as:

$$\tilde{P}_1(k) = \frac{\tilde{\beta}_1 \tilde{P}_1}{\tilde{\lambda}_1(k)} , \text{ for } k \in K , \qquad \text{Eq (18)}$$

where $\tilde{\beta}_1$ is a normalization factor that keeps the total transmit power invariant after channel inversion is applied;
$\tilde{P}_1$ is the transmit power allocated to each of the four antennas; and
$\tilde{\lambda}_1(k)$ is the power gain for subband k of the principal eigenmode for the beam-steering mode.
The normalization factor $\tilde{\beta}_1$ may be expressed as:

$$\tilde{\beta}_1 = \frac{1}{\sum_{k \in K} \tilde{\lambda}_1^{-1}(k)} . \qquad \text{Eq (19)}$$

The transmit power $\tilde{P}_1$ may be given as $P_1 = P_{total}/4$ (i.e., uniform allocation of the total transmit power across the four transmit antennas). The power gain $\tilde{\lambda}_1(k)$ may be expressed as:

$$\tilde{\lambda}_1(k) = \underline{\tilde{v}}^H(k)\underline{\mathbf{H}}^H(k)\underline{\mathbf{H}}(k)\underline{\tilde{v}}(k) . \qquad \text{Eq (20)}$$

[0260] The channel inversion results in power allocation of $\tilde{P}_1(k)$, for $k \in K$, for the 48 data subbands. The gain for each data subband may then be given as $\tilde{g}(k) = \sqrt{\tilde{P}_1(k)}$.

[0261] For the beam-steering mode, the transmit vector $\underline{x}(k)$ for each subband may be expressed as:

$$\underline{x}(k) = \underline{\tilde{v}}(k)\tilde{g}(k)s(k) \text{ , for } k \in K . \qquad \text{Eq (21)}$$

Again for simplicity, equation (21) does not include the correction factors used to account for differences between the transmit/receive chains at the access point and the user terminal.

[0262] As shown in equation (16), the four elements of the normalized steering vector $\underline{\tilde{v}}(k)$ for each subband have equal magnitude but possibly different phases. The beam-steering thus generates one transmit vector $\underline{x}(k)$ for each subband, with the four elements of $\underline{x}(k)$ having the same magnitude but possibly different phases.

[0263] **FIG. 10B** shows a block diagram of an embodiment of TX spatial processor 720c capable of performing the spatial processing for the beam-steering mode.

[0264] Within processor 720c, a demultiplexer 1032 receives and demultiplexes the modulation symbol stream $s(n)$ into 48 substreams for the 48 data subbands (denoted as $s(1)$ through $s(k)$). Each symbol substream is provided to a respective TX subband beam-steering processor 1040. Each processor 1040 performs the processing shown in equation (14) for one subband.

[0265] Within each TX subband beam-steering processor 1040, the modulation symbol substream is provided to a multiplier 1042, which also receives the gain $\tilde{g}(k)$ for the associated subband. Multiplier 1042 then scales the modulation symbols with the gain $\tilde{g}(k)$ to obtain scaled modulation symbols, which are then provided to a beam-steering unit 1050.

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[0266] Beam-steering unit 1050 also receives the normalized eigenvector $\underline{\tilde{v}}(k)$ for the associated subband. Within beam-steering unit 1050, the scaled modulation symbols are provided to four multipliers 1052a through 1052d, which also respectively receive the four elements, $\tilde{v}_1(k)$, $\tilde{v}_2(k)$, $\tilde{v}_3(k)$, and $\tilde{v}_4(k)$, of the normalized eigenvector $\underline{\tilde{v}}(k)$. Each multiplier 1052 multiplies its scaled modulation symbols with its normalized eigenvector value $\tilde{v}_i(k)$ to provide preconditioned symbols. Multipliers 1052a through 1052d provide four preconditioned symbol substreams to buffers/multiplexers 1070a through 1070d, respectively.

[0267] Each buffer/multiplexer 1070 receives pilot symbols and the preconditioned symbols from TX subband beam-steering processors 1040a through 1040k for the 48 data subbands, multiplexes the pilot and preconditioned symbols and zeros for each symbol period, and provides a stream of transmit symbols $x_i(n)$ for one transmit antenna. The subsequent OFDM modulation for each transmit symbol stream is described above.

[0268] The processing for the beam-steering mode is described in further detail in commonly assigned U.S. Patent Application Serial No. 10/228,393, entitled "Beam-Steering and Beam-Forming for Wideband MIMO Systems," filed August 27, 2002. The system may also be designed to support a beam-forming mode whereby a data stream is transmitted on the principal eigenmode using the eigenvector instead of the normalized eigenvector.

4. Framing for PHY frames

[0269] **FIG. 11A** shows an embodiment of framing unit 808, which is used to frame the data for each FCH/RCH packet prior to subsequent processing by the TX data processor. This framing function may be bypassed for messages sent on the BCH, FCCH, and RACH. The framing unit generates an integer number of PHY frames for each FCH/RCH packet, where each PHY frame spans 6 OFDM symbols for the embodiment described herein.

[0270] For the diversity and beam-steering modes, only one spatial channel or wideband eigenmode is used for data transmission. The rate for this mode is known, and the number of information bits that may be sent in the payload of each PHY frame may be computed. For the spatial multiplexing mode, multiple spatial channels may be used for data transmission. Since the rate of each spatial channel is known, the number of information bits that may be sent in the payload of each PHY frame for all spatial channels may be computed.

[0271] As shown in FIG. 11A, the information bits (denoted as $i_1\ i_2\ i_3\ i_4$ ...) for each FCH/RCH packet are provided to a CRC generator 1102 and a multiplexer 1104 within framing unit 808. CRC generator 1102 generates a CRC value for the bits in the header (if any) and payload fields of each PHY frame and provides CRC bits to multiplexer 1104. Multiplexer 1104 receives the information bits, CRC bits, header bits, and pad bits (e.g., zeros), and provides these bits in the proper order, as shown in FIG. 6, based on a PHY Frame Control signal. The framing function may be bypassed by providing the information bits directly through multiplexer 1104. The framed or unframed bits (denoted as $d_1\ d_2\ d_3\ d_4$ ...) are provided to scrambler 810.

5. Scrambling

[0272] In an embodiment, the data bits for each transport channel are scrambled prior to coding. The scrambling randomizes the data so that a long sequence of all ones or all zeros is not transmitted. This can reduce the variation in the peak to average power of the OFDM waveform. The scrambling may be omitted for one or more transport channels and may also be selectively enabled and disabled.

[0273] FIG. 11A also shows an embodiment of scrambler 810. In this embodiment, scrambler 810 implements a generator polynomial:

$$G(x) = x^7 + x^4 + x \quad . \qquad \text{Eq (22)}$$

Other generator polynomials may also be used, and this is within the scope of the invention.

[0274] As shown in FIG. 11A, scrambler 810 includes seven delay elements 1112a through 1112g coupled in series. For each clock cycle, an adder 1114 performs modulo-2 addition of two bits stored in delay elements 1112d and 1112g and provides a scrambling bit to delay element 1112a.

[0275] The framed/unframed bits ($d_1\ d_2\ d_3\ d_4$ ...) are provided to an adder 1116, which also receives scrambling bits from adder 1114. Adder 1116 performs modulo-2 addition of each bit d_n with a corresponding scrambling bit to provide a scrambled bit q_n. Scrambler 810 provides a sequence of scrambled bits, which is denoted as $q_1\ q_2\ q_3\ q_4$ .... .

[0276] The initial state of the scrambler (i.e., the content of delay elements 1112a through 1112g) is set to a 7-bit non-zero number at the start of each TDD frame. The three most significant bits (MSBs) (i.e., delay element 1112e through 1112f) are always set to one ('1') and the four least significant bits (LSBs) are set to the TDD frame counter, as indicated in the BCH message.

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6. Encoding/Puncturing

[0277] In an embodiment, a single base code is used to code data prior to transmission. This base code generates code bits for one code rate. All other code rates supported by the system (as listed in Table 25) may be obtained by either repeating or puncturing the code bits.

[0278] **FIG. 11B** shows an embodiment of encoder 812 that implements the base code for the system. In this embodiment, the base code is a rate 1/2, constraint length 7 (K = 7), convolutional code with generators of 133 and 171 (octal).

[0279] Within encoder 812, a multiplexer 1120 receives and multiplexes the scrambled bits and tail bits (e.g., zeros). Encoder 812 further includes six delay elements 1122a through 1122f coupled in series. Four adders 1124a through 1124d are also coupled in series and used to implement the first generator (133). Similarly, four adders 1126a through 1126d are coupled in series and used to implement the second generator (171). The adders are further coupled to the delay elements in a manner to implement the two generators of 133 and 171, as shown in FIG. 11B.

[0280] The scrambled bits are provided to the first delay element 1122a and to adders 1124a and 1126a. For each clock cycle, adders 1124a through 1124d perform modulo-2 addition of the incoming bit and four prior bits stored in delay elements 1122b, 1122c, 1122e, and 1122f to provide the first code bit for that clock cycle. Similarly, adders 1126a through 1126d perform modulo-2 addition of the incoming bit and four prior bits stored in delay elements 1122a, 1122b, 1122c, and 1122f to provide the second code bit for that clock cycle. The code bits generated by the first generator are denoted as $a_1\ a_2\ a_3\ a_4$ ..., and the code bits generated by the second generator are denoted as $b_1\ b_2\ b_3\ b_4$ .... A multiplexer 1128 then receives and multiplexes the two streams of code bits from the two generators into a single stream of code bits, which is denoted as $a_1\ b_1\ a_2\ b_2\ a_3\ b_3\ a_4\ b_4$ .... For each scrambled bit q_n, two code bits a_n and b_n are generated, which results in a code rate of 1/2.

[0281] FIG. 11B also shows an embodiment of repeat/puncture unit 814 that can be used to generate other code rates based on the base code rate of 1/2. Within unit 814, the rate 1/2 code bits from encoder 812 are provided to a repeating unit 1132 and a puncturing unit 1134. Repeating unit 1132 repeats each rate 1/2 code bit once to obtain an effective code rate of 1/4. Puncturing unit 1134 deletes some of the rate 1/2 code bits based on a specific puncturing pattern to provide the desired code rate.

[0282] Table 30 lists exemplary puncturing patterns that may be used for the various code rates supported by the system. Other puncturing patterns may also be used, and this is within the scope of the invention.

Table 30

Code Rate	Puncturing Pattern
1/2	11
7/12	11111110111110
5/8	1110111011
2/3	1110
11/16	11111011111110010011100
3/4	111001
13/16	01111011111101110000101100
5/6	1110011001
7/8	11101010011001

[0283] To obtain a code rate of k / n, puncturing unit 1134 provides n code bits for each group of 2k rate 1/2 code bits received from encoder 812. Thus, $2k$-n code bits are deleted from each group of $2k$ code bits. The bits to be deleted from each group are denoted by zeros in the puncturing pattern. For example, to obtain a code rate of 7/12, two bits are deleted from each group of 14 code bits from encoder 812, with the deleted bits being the 8th and 14th code bits in the group, as denoted by the puncturing pattern of "11111110111110". No puncturing is performed if the desired code rate is 1/2.

[0284] A multiplexer 1136 receives the stream of code bits from repeating unit 1132 and the stream of code bits from puncturing unit 1134. Multiplexer 1136 then provides the code bits from repeating unit 1132 if the desired code rate is 1/4 and the code bits from puncturing unit 1134 if the desired code rate is 1/2 or higher.

[0285] Other codes and puncturing patterns besides those described above may also be used, and this is within the scope of the invention. For example, a Turbo code, a block code, some other codes, or any combination thereof may be used to code data. Also, different coding schemes may be used for different transport channels. For example,

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convolutional coding may be used for the common transport channels, and Turbo coding may be used for the dedicated transport channels.

7. Interleaving

[0286] In an embodiment, the code bits to be transmitted are interleaved across the 48 data subbands. For the diversity and beam-steering modes, one stream of code bits is transmitted and interleaved across all data subbands. For the spatial multiplexing mode, up to four streams of code bits may be transmitted on up to four spatial channels. The interleaving may be performed separately for each spatial channel such that each stream of code bits is interleaved across all data subbands of the spatial channel used to transmit that stream. Table 29 shows an exemplary code bit-subband assignment that may be used for the interleaving for all transmission modes.

[0287] In one embodiment, the interleaving is performed across all 48 data subbands in each interleaving interval. For this embodiment, each group of 48 code bits in a stream is spread over the 48 data subbands to provide frequency diversity. The 48 code bits in each group may be assigned indices of 0 through 47. Each code bit index is associated with a respective subband. All code bits with a particular index are transmitted on the associated subband. For example, the first code bit (with index 0) in each group is transmitted on subband -26, the second code bit (with index 1) is transmitted on subband 1, the third code bit (with index 2) is transmitted on subband -17, and so on. This interleaving scheme may be used for the diversity, beam-steering, and spatial multiplexing modes. An alternative interleaving scheme for the spatial multiplexing mode is described below.

[0288] The interleaving may alternatively or additionally be performed over time. For example, after the interleaving across the data subbands, the code bits for each subband may further be interleaved (e.g., over one PHY frame or one PDU) to provide time diversity. For the spatial multiplexing mode, the interleaving may also be performed over multiple spatial channels.

[0289] Additionally, interleaving may be employed across the dimensions of the QAM symbols such that code bits forming QAM symbols are mapped to different bit positions of the QAM symbols.

8. Symbol Mapping

[0290] Table 31 shows the symbol mapping for various modulation schemes supported by the system. For each modulation scheme (except for BPSK), half of the bits are mapped to an inphase (I) component and the other half of the bits are mapped to a quadrature (Q) component.

[0291] In an embodiment, the signal constellation for each supported modulation scheme may be defined based on Gray mapping. With Gray mapping, neighboring points in the signal constellation (in both the I and Q components) differ by only one bit position. Gray mapping reduces the number of bit errors for more likely error events, which corresponds to a received symbol being mapped to a location near the correct location, in which case only one code bit would be received in error.

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Table 31

BPSK		
b	I	Q
0	-1	0
1	1	0

QPSK			
b_0	I	b_1	Q
0	-1	0	-1
1	1	1	1

16 QAM			
b_0b_1	I	b_2b_3	Q
00	-3	00	-3
01	-1	01	-1
11	1	11	1
10	3	10	3

64 QAM			
$b_0b_1b_2$	I	$b_3b_4b_5$	Q
000	-7	000	-7
001	-5	001	-5
011	-3	011	-3
010	-1	010	-1
110	1	110	1
111	3	111	3
101	5	101	5
100	7	100	7

256 QAM			
$b_0b_1b_2b_3$	I	$b_4b_5b_6b_7$	Q
0000	-15	0000	-15
0001	-13	0001	-13
0011	-11	0011	-11
0010	-9	0010	-9
0110	-7	0110	-7
0111	-5	0111	-5
0101	-3	0101	-3
0100	-1	0100	-1
1100	1	1100	1
1101	3	1101	3
1111	5	1111	5
1110	7	1110	7
1010	9	1010	9
1011	11	1011	11
1001	13	1001	13
1000	15	1000	15

Normalization Factor K_{norm}	
Modulation Scheme	Value
BPSK	1.0
QPSK	$1/\sqrt{2}$
16 QAM	$1/\sqrt{10}$
64 QAM	$1/\sqrt{42}$
256 QAM	$1/\sqrt{170}$

[0292] The I and Q values for each modulation scheme shown in Table 31 are scaled by a normalization factor K_{norm}

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so that the average power of all signal points in the associated signal constellation is equal to unity. The normalization factor for each modulation scheme is shown in Table 31. Quantized values for the normalization factors for the supported modulation schemes may also be used. A modulation symbol s from a particular signal constellation would then have the following form:

$$s = (I + jQ) \cdot K_{norm} \quad ,$$

where I and Q are the values in Table 31 for the signal constellation.

[0293] For a given PDU, the modulation may be different across the PDU and may be different for multiple spatial channels used for data transmission. For example, for the BCH PDU, different modulation schemes may be used for the beacon pilot, the MIMO pilot, and the BCH message.

9. Processing for Spatial Multiplexing Mode

[0294] For the spatial multiplexing mode, a PDU may be transmitted over multiple spatial channels. Various schemes may be used to process data for transmission over multiple spatial channels. Two specific processing schemes for the spatial multiplexing mode are described below.

[0295] In the first processing scheme, coding and puncturing are performed on a per spatial channel basis to achieve the desired code rate for each spatial channel. The N_E spatial channels to use for data transmission are ranked from the highest to lowest received SNR. The data for the entire PDU is first coded to obtain a stream of rate 1/2 code bits. The code bits are then punctured to obtain the desired code rate for each spatial channel.

[0296] The puncturing may be performed in sequential order for the N_E spatial channels, from the best (i.e., highest SNR) to the worst (i.e., lowest SNR) spatial channel. In particular, the puncture unit first performs puncturing for the best spatial channel with the highest received SNR. When the correct number of code bits have been generated for the best spatial channel, the puncture unit then performs puncturing for the second best spatial channel with the next highest received SNR. This process continues until the code bits for all N_E spatial channels are generated. The order for puncturing is from the largest to smallest received SNR, regardless of the specific code rate used for each spatial channel.

[0297] For the example shown in Table 28, the 3456 information bits to be transmitted in the overall PHY frame are first coded with the rate 1/2 base code to obtain 6912 code bits. The first 3168 code bits are punctured using the puncturing pattern for code rate 11/16 to obtain 2304 code bits, which are provided in the PHY frame for the first spatial channel. The next 2592 code bits are then punctured using the puncturing pattern for code rate 3/4 to obtain 1728 code bits, which are provided in the PHY frame for the second spatial channel. The next 864 code bits are then punctured using the puncturing pattern for code rate 3/4 to obtain 576 code bits, which are provided in the PHY frame for the third spatial channel. The last 288 code bits for the PHY frame are then punctured using the puncturing pattern for code rate 1/2 to obtain 288 code bits, which are provided in the PHY frame for the last spatial channel. These four individual PHY frames are further processed and transmitted on the four spatial channels. The puncturing for the next overall PHY frame is then performed in similar manner. The first processing scheme may be implemented by TX data processor 710b in FIG. 9A.

[0298] In the second processing scheme, the coding and puncturing are performed for pairs of subbands. Moreover, the coding and puncturing are cycled through all selected spatial channels for each pair of subbands.

[0299] **FIG. 11C** shows a block diagram that illustrates a TX data processor 710d that implements the second processing scheme. Encoder 812 performs rate 1/2 convolutional encoding of the scrambled bits from scrambler 810. Each spatial channel is assigned a particular rate, which is associated with a specific combination of code rate and modulation scheme, as shown in Table 25. Let b_m denote the number of code bits per modulation symbol for spatial channel m (or equivalently, the number of code bits sent on each data subband of spatial channel m) and r_m denote the code rate used for spatial channel m. The value for b_m is dependent on the constellation size of the modulation scheme used for spatial channel m. In particular, $b_m = 1, 2, 4, 6$ and 8 for BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM, respectively.

[0300] Encoder 812 provides a stream of rate 1/2 code bits to demultiplexer 816, which demultiplexes the received code bit stream into four substreams for the four spatial channels. The demultiplexing is such that the first $4b_1r_1$ code bits are sent to buffer 813a for spatial channel 1, the next $4b_2r_2$ code bits are sent to buffer 813b for spatial channel 2, and so on. Each buffer 813 receives $4b_mr_m$ code bits each time demultiplexer 816 cycles through all four spatial channels. A total of $b_{total} = \sum_{m=1}^{4} 4b_mr_m$ rate 1/2 code bits are provided to the four buffers 813a through 813d for each cycle. Demultiplexer 816 thus cycles through all four positions for the four spatial channels for every b_{total} code bits, which is the number of code bits that can be sent on a pair of subbands using all four spatial channels.

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[0301] Once each buffer 813 has been filled with $4b_m r_m$ code chips for the associated spatial channel, the code bits in the buffer are punctured to obtain the code rate for that spatial channel. Since $4b_m r_m$ rate 1/2 code bits span an integer number of puncturing periods for each puncturing pattern, exactly $2b_m$ code bits are provided after the puncturing for each spatial channel m. The $2b_m$ code bits for each spatial channel are then distributed (interleaved) over the data subbands.

[0302] In an embodiment, the interleaving is performed for each spatial channel in groups of 6 subbands at a time. The code bits after the puncturing for each spatial channel may be numbered sequentially as c_i, for $i = 0, 1, 2, \ldots$. A counter C_m may be maintained for each spatial channel to count every group of $6b_m$ code bits provided by the puncturing unit for that spatial channel. For example, for QPSK with $b_m = 2$, the counter would be set to $C_m = 0$ for code bits c_0 through c_{11} provided by the puncturing unit, $C_m = 1$ after code bits c_{12} through c_{23}, and so on. The counter value C_m for spatial channel m may be expressed as:

$$C_m = \lfloor i/(6b_m) \rfloor \bmod 8 \quad . \qquad \text{Eq (23)}$$

[0303] To determine the subband to which code bit c_i is assigned, the bit index for the code bit is first determined as follows:

$$\text{bit index} = (i \bmod 6) + 6 \cdot C_m \quad . \qquad \text{Eq (24)}$$

The bit index is then mapped to the corresponding subband using Table 29.

[0304] For the example above, the first group of 6 code bits c_0 through c_5 is associated with bit indices 0 through 5, respectively, the second group of 6 code bits c_6 through c_{11} is also associated with bit indices 0 through 5, respectively. Code bits c_0 and c_6 would be mapped to subband -26, code bits c_1 and c_7 would be mapped to subband 1, and so on, as shown in Table 29. The spatial processing may then commence for this first group of 6 subbands. The third group of 6 code bits c_{12} through c_{17} (with $C_m = 1$) is associated with bit indices 6 through 11, respectively, and the fourth group of 6 code bits c_{18} through c_{23} is also associated with bit indices 6 through 11, respectively. Code bits c_{12} and c_{18} would be mapped to subband -25, code bits c_{13} and c_{19} would be mapped to subband 2, and so on. The spatial processing may then commence for this next group of 6 subbands.

[0305] The number 6 in equation (24) comes from the fact that the interleaving is performed in groups of six subbands. The (mod 8) operation in equation (23) comes from the fact that there are eight interleaving groups for the 48 data subbands. Since each cycle of demultiplexer 816 shown in FIG. 11C produces enough code bits to fill two subbands for each wideband eigenmode, a total of 24 cycles are needed to provide the $48b_m$ code bits for one OFDM symbol for each spatial channel.

[0306] The interleaving in groups of 6 subbands at a time can reduce processing delays. In particular, the spatial processing can commence once each group of 6 subbands is available.

[0307] In alternative embodiments, the interleaving may be performed for each spatial channel in groups of N_B subbands at a time, where N_B may be any integer (e.g., N_B may be equal to 48 for interleaving over all 48 data subbands).

VI. Calibration

[0308] For a TDD system, the downlink and uplink share the same frequency band in a time division duplexed manner. In this case, a high degree of correlation typically exists between the downlink and uplink channel responses. This correlation may be exploited to simplify the channel estimation and spatial processing. For a TDD system, each subband of the wireless link may be assumed to be reciprocal. That is, if $\underline{\mathbf{H}}(k)$ represents the channel response matrix from antenna array A to antenna array B for subband k, then a reciprocal channel implies that the coupling from array B to array A is given by the transpose of $\underline{\mathbf{H}}(k)$, which is $\underline{\mathbf{H}}^T(k)$.

[0309] However, the responses (gain and phase) of the transmit and receive chains at the access point are typically different from the responses of the transmit and receive chains at the user terminal. Calibration may be performed to determine the difference in the frequency responses of the transmit/receive chains at the access point and user terminal, and to account for the difference, such that the calibrated downlink and uplink responses can be expressed in terms of each other. Once the transmit/receive chains have been calibrated and accounted for, a measurement for one link (e.g., the downlink) may be used to derive steering vectors for the other link (e.g., the uplink).

[0310] The "effective" downlink and uplink channel responses, $\underline{\mathbf{H}}_{dn}(k)$ and $\underline{\mathbf{H}}_{up}(k)$, which include the responses of the applicable transmit and receive chains at the access point and user terminal, may be expressed as:

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$$\underline{\mathbf{H}}_{dn}(k) = \underline{\mathbf{R}}_{ut}(k)\underline{\mathbf{H}}(k)\underline{\mathbf{T}}_{ap}(k) \ , \text{ for } k \in K, \text{ and} \qquad \text{Eq (25)}$$

$$\underline{\mathbf{H}}_{up}(k) = \underline{\mathbf{R}}_{ap}(k)\underline{\mathbf{H}}^{T}(k)\underline{\mathbf{T}}_{ut}(k) \ , \text{for } k \in K,$$

where $\underline{\mathbf{T}}_{ap}(k)$ and $\underline{\mathbf{R}}_{ap}(k)$ are $N_{ap} \times N_{ap}$ diagonal matrices with entries for the complex gains associated with the transmit chain and receive chain, respectively, for the N_{ap} antennas at the access point for subband k;
$\underline{\mathbf{T}}_{ut}(k)$ and $\underline{\mathbf{R}}_{ut}(k)$ are $N_{ut} \times N_{ut}$ diagonal matrices with entries for the complex gains associated with the transmit chain and receive chain, respectively, for the N_{ut} antennas at the user terminal for subband k; and
$\underline{\mathbf{H}}(k)$ is an $N_{ut} \times N_{ap}$ channel response matrix for the downlink.

[0311] Combining the two equations in equation set (25), the following relationship may be obtained:

$$\underline{\mathbf{H}}_{up}(k)\underline{\mathbf{K}}_{ut}(k) = (\underline{\mathbf{H}}_{dn}(k)\underline{\mathbf{K}}_{ap}(k))^{T} \ , \text{ for } k \in K, \qquad \text{Eq (26)}$$

where

$$\underline{\mathbf{K}}_{ut}(k) = \underline{\mathbf{T}}_{ut}^{-1}(k)\underline{\mathbf{R}}_{ut}(k) \text{ and } \underline{\mathbf{K}}_{ap}(k) = \underline{\mathbf{T}}_{ap}^{-1}(k)\underline{\mathbf{R}}_{ap}(k).$$

[0312] The left-hand side of equation (26) represents the "true" calibrated channel response on the uplink, and the right-hand side represents the transpose of the "true" calibrated channel response on the downlink. The application of the diagonal matrices $\underline{\mathbf{K}}_{ap}(k)$ and $\underline{\mathbf{K}}_{ut}(k)$ to the effective downlink and uplink channel responses, respectively, as shown in equation (26), allows the calibrated channel responses for the downlink and uplink to be expressed as transposes of each other. The $(N_{ap} \times N_{ap})$ diagonal matrix $\underline{\mathbf{K}}_{ap}(k)$ for the access point is the ratio of the receive chain response $\underline{\mathbf{R}}_{ap}(k)$ to the transmit chain response $\underline{\mathbf{T}}_{ap}(k)$ (i.e., $\underline{\mathbf{K}}_{ap}(k) = \frac{\underline{\mathbf{R}}_{ap}(k)}{\underline{\mathbf{T}}_{ap}(k)}$), where the ratio is taken element-by-element. Similarly, the $(N_{ut} \times N_{ut})$ diagonal matrix $\underline{\mathbf{K}}_{ut}(k)$ for the user terminal is the ratio of the receive chain response $\underline{\mathbf{R}}_{ut}(k)$ to the transmit chain response $\underline{\mathbf{T}}_{ut}(k)$.

[0313] The matrices $\underline{\mathbf{K}}_{ap}(k)$ and $\underline{\mathbf{K}}_{ut}(k)$ include values that can account for differences in the transmit/receive chains at the access point and the user terminal. This would then allow the channel response for one link to be expressed by the channel response for the other link, as shown in equation (26).

[0314] Calibration may be performed to determine the matrices $\underline{\mathbf{K}}_{ap}(k)$ and $\underline{\mathbf{K}}_{ut}(k)$. Typically, the true channel response $\underline{\mathbf{H}}(k)$ and the transmit/receive chain responses are not known nor can they be exactly or easily ascertained. Instead, the effective downlink and uplink channel responses, $\underline{\mathbf{H}}_{dn}(k)$ and $\underline{\mathbf{H}}_{up}(k)$, may be estimated based on pilots sent on the downlink and uplink, respectively, as described below. Estimates of the matrices $\underline{\mathbf{K}}_{ap}(k)$ and $\underline{\mathbf{K}}_{ut}(k)$, which are referred to as correction matrices $\hat{\underline{\mathbf{K}}}_{ap}(k)$ and $\hat{\underline{\mathbf{K}}}_{ut}(k)$, may then be derived based on the downlink and uplink channel response estimates, $\hat{\underline{\mathbf{H}}}_{dn}(k)$ and $\hat{\underline{\mathbf{H}}}_{up}(k)$, as described below. The matrices $\hat{\underline{\mathbf{K}}}_{ap}(k)$ and $\hat{\underline{\mathbf{K}}}_{ut}(k)$ include correction factors that can account for differences in the transmit/receive chains at the access point and the user terminal.

[0315] The "calibrated" downlink and uplink channel responses observed by the user terminal and the access point, respectively, may then be expressed as:

$$\underline{\mathbf{H}}_{cdn}(k) = \underline{\mathbf{H}}_{dn}(k)\hat{\underline{\mathbf{K}}}_{ap}(k) \ , \text{ for } k \in K, \text{ and} \qquad \text{Eq (27)}$$

$$\underline{\mathbf{H}}_{cup}(k) = \underline{\mathbf{H}}_{up}(k)\hat{\underline{\mathbf{K}}}_{ut}(k) \ , \text{ for } k \in K,$$

where $\underline{\mathbf{H}}_{cdn}^{T}(k)$ and $\underline{\mathbf{H}}_{cup}(k)$ are estimates of the "true" calibrated channel response expressions in equation (26). Combining the two equations in equation set (27) using the expression in equation (26), it can be shown that $\underline{\mathbf{H}}_{cup}(k) \approx \underline{\mathbf{H}}_{cdn}^{T}(k)$. The accuracy of the relationship $\underline{\mathbf{H}}_{cup}(k) \approx \underline{\mathbf{H}}_{cdn}^{T}(k)$ is dependent on the accuracy of the

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matrices $\hat{\underline{K}}_{ap}(k)$ and $\hat{\underline{K}}_{ut}(k)$, which in turn is typically dependent on the quality of the downlink and uplink channel response estimates, $\hat{\underline{H}}_{dn}(k)$ and $\hat{\underline{H}}_{up}(k)$.

[0316] The calibration may be performed using various schemes. For clarity, a specific calibration scheme is described below. To perform the calibration, the user terminal initially acquires the timing and frequency of the access point based on the beacon pilot transmitted on the BCH. The user terminal then sends a message on the RACH to initiate a calibration procedure with the access point. The calibration may be performed in parallel with registration/ authentication.

[0317] Since the frequency responses of the transmit/receive chains at the access point and user terminal are typically flat over most of the band of interest, the phase/gain differences of the transmit/receive chains may be characterized with a small number of subbands. The calibration may be performed for 4, 8, 16, 48 or some other number of subbands, which may be specified in the message sent to initiate the calibration. Calibration may also be performed for the pilot subbands. Calibration constants for subbands on which calibration is not explicitly performed may be computed by interpolation on calibrated subbands. For clarity, the following assumes that calibration is performed for all data subbands.

[0318] For the calibration, the access point allocates to the user terminal a sufficient amount of time on the RCH to send an uplink MIMO pilot of sufficient duration plus a message. The duration of the uplink MIMO pilot may be dependent on the number of subbands over which calibration is performed. For example, 8 OFDM symbols may be sufficient if calibration is performed for four subbands, and more (e.g., 20) OFDM symbols may be needed for more subbands. The total transmit power is typically fixed, so if the MIMO pilot is transmitted on a small number of subbands, then higher amounts of transmit power may be used for each of these subbands and the SNR for each subband is high. Conversely, if the MIMO pilot is transmitted on a large number of subbands then smaller amounts of transmit power may be used for each subband and the SNR for each subband is worse. If the SNR of each subband is not sufficiently high, then more OFDM symbols may be sent for the MIMO pilot and integrated at the receiver to obtain a higher overall SNR for the subband.

[0319] The user terminal then transmits a MIMO pilot on the RCH, which is used by the access point to derive an estimate of the effective uplink channel response, $\hat{\underline{H}}_{up}(k)$, for each of the data subbands. The uplink channel response estimates are quantized (e.g., to 12-bit complex values, with inphase (I) and quadrature (Q) components) and sent to the user terminal.

[0320] The user terminal also derives an estimate of the effective downlink channel response, $\hat{\underline{H}}_{dn}(k)$, for each of the data subbands based on the downlink MIMO pilot sent on the BCH. Upon obtaining the effective uplink and downlink channel response estimates, $\hat{\underline{H}}_{up}(k)$ and $\hat{\underline{H}}_{dn}(k)$, for all data subbands, the user terminal determines correction factors, $\hat{\underline{K}}_{ap}(k)$ and $\hat{\underline{K}}_{ut}(k)$, for each of the data subbands, which are to be used by the access point and user terminal, respectively. A correction vector $\hat{\underline{k}}_{ap}(k)$ may be defined to include only the diagonal elements of $\hat{\underline{K}}_{ap}(k)$, and a correction vector $\hat{\underline{k}}_{ut}(k)$ may be defined to include only the diagonal elements of $\hat{\underline{K}}_{ut}(k)$.

[0321] The correction factors may be derived in various manners, including by a matrix-ratio computation and an MMSE computation. Both of these computation methods are described in further detail below. Other computation methods may also be used, and this is within the scope of the invention.

1. Matrix-Ratio Computation

[0322] To determine the correction vectors $\hat{\underline{k}}_{ap}(k)$ and $\hat{\underline{k}}_{ut}(k)$ given the effective downlink and uplink channel response estimates, $\hat{\underline{H}}_{dn}(k)$ and $\hat{\underline{H}}_{up}(k)$, an $(N_{ut} \times N_{ap})$ matrix $\underline{C}(k)$ is first computed for each data subband, as follows:

$$\underline{C}(k) = \frac{\hat{\underline{H}}_{up}^{T}(k)}{\hat{\underline{H}}_{dn}(k)} \quad , \text{for } k \in K \ , \qquad \text{Eq (28)}$$

where the ratio is taken element-by-element. Each element of $\underline{C}(k)$ may thus be computed as:

$$c_{i,j}(k) = \frac{\hat{h}_{up\,i,j}(k)}{\hat{h}_{dn\,i,j}(k)} \quad , \text{ for } i = \{1 \ldots N_{ut}\} \text{ and } j = \{1 \ldots N_{ap}\} , \qquad \text{Eq (29)}$$

where $\hat{h}_{upi,j}(k)$ is the (i,j)-th (row, column) element of $\hat{\underline{H}}_{up}^{T}(k)$, $\hat{h}_{dni,j}(k)$ is the (i,j)-th element of $\hat{\underline{H}}_{dn}(k)$, and $c_{i,j}(k)$ is the (i,j)-th element of $\underline{C}(k)$.

[0323] The correction vector $\hat{\underline{k}}_{ap}(k)$ for the access point is then equal to the mean of the normalized rows of $\underline{C}(k)$. Each

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row of $\underline{C}(k)$ is first normalized by scaling each of the N_{ap} elements in the row with the first element in the row. Thus, if $\underline{c}_i(k) = [c_{i,1}(k) \ldots c_{i,Nap}(k)]$ is the i-th row of $\underline{C}(k)$, then the normalized row $\underline{\tilde{c}}_i(k)$ may be expressed as:

$$\underline{\tilde{c}}_i(k) = [c_{i,1}(k)/c_{i,1}(k) \ \ldots \ c_{i,j}(k)/c_{i,1}(k) \ \ldots \ c_{i,N_{ap}}(k)/c_{i,1}(k)] \ . \qquad \text{Eq (30)}$$

The mean of the normalized rows is then the sum of the N_{ut} normalized rows divided by N_{ut}, which may be expressed as:

$$\hat{\underline{k}}_{ap}(k) = \frac{1}{N_{ut}} \sum_{i=1}^{N_{ut}} \underline{\tilde{c}}_i(k) \ , \text{for } k \in K . \qquad \text{Eq (31)}$$

Because of the normalization, the first element of $\hat{\underline{k}}_{ap}(k)$ is unity.

[0324] The correction vector $\hat{\underline{k}}_{ut}(k)$ for the user terminal is equal to the mean of the inverses of the normalized columns of $\underline{C}(k)$. The j-th column of $\underline{C}(k)$ is first normalized by scaling each element in the column with the j-th element of the vector $\hat{\underline{k}}_{ap}(k)$, which is denoted as $K_{ap,j,j}(k)$. Thus, if $\underline{c}_j(k) = [c_{1,j}(k) \ldots c_{Nut,j}(k)]^T$ is the j-th column of $\underline{C}(k)$, then the normalized column $\underline{c}_j(k)$ may be expressed as:

$$\underline{\tilde{c}}_j(k) = [c_{1,j}(k)/K_{ap,j,j}(k) \ \ldots \ c_{i,j}(k)/K_{ap,j,j}(k) \ \ldots \ c_{N_{ut},j}(k)/K_{ap,j,j}(k)]^T . \qquad \text{Eq (32)}$$

The mean of the inverses of the normalized columns is then the sum of the inverses of the N_{ap} normalized columns divided by N_{ap}, which may be expressed as:

$$\hat{\underline{k}}_{ut}(k) = \frac{1}{N_{ap}} \sum_{j=1}^{N_{ap}} \frac{1}{\underline{\tilde{c}}_j(k)} \ , \text{for } k \in K , \qquad \text{Eq (33)}$$

where the inversion of the normalized columns, $\underline{c}_j(k)$, is performed element-wise.

2. MMSE Computation

[0325] For the MMSE computation, the correction factors $\hat{\underline{K}}_{ap}(k)$ and $\hat{\underline{K}}_{ut}(k)$ are derived from the effective downlink and uplink channel response estimates, $\hat{\underline{H}}_{dn}(k)$ and $\hat{\underline{H}}_{up}(k)$, such that the mean square error (MSE) between the calibrated downlink channel response and the calibrated uplink channel response is minimized. This condition may be expressed as:

$$\min \left| (\hat{\underline{H}}_{dn}(k)\hat{\underline{K}}_{ap}(k))^T - (\hat{\underline{H}}_{up}(k)\hat{\underline{K}}_{ut}(k)) \right|^2 \ , \text{for } k \in K , \qquad \text{Eq (34)}$$

which may also be written as:

$$\min \left| \hat{\underline{K}}_{ap}(k)\hat{\underline{H}}_{dn}^T(k) - \hat{\underline{H}}_{up}(k)\hat{\underline{K}}_{ut}(k) \right|^2 \ , \text{for } k \in K ,$$

where $\hat{\underline{K}}_{ap}^T(k) = \hat{\underline{K}}_{ap}(k)$ since $\hat{\underline{K}}_{ap}(k)$ is a diagonal matrix.

[0326] Equation (34) is subject to the constraint that the lead element of $\hat{\underline{K}}_{ap}(k)$ is set equal to unity (i.e., $\hat{\underline{K}}_{ap0,0}(k) = 1$). Without this constraint, the trivial solution would be obtained with all elements of the matrices $\hat{\underline{K}}_{ap}(k)$ and $\hat{\underline{K}}_{ut}(k)$ set equal to zero. In equation (34), a matrix $\underline{Y}(k)$ is first obtained as $\underline{Y}(k) = \hat{\underline{K}}_{ap}(k)\hat{\underline{H}}_{dn}^T(k) - \hat{\underline{H}}_{up}(k)\hat{\underline{K}}_{ut}(k)$. The

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square of the absolute value is next obtained for each of the $N_{ap} \cdot N_{ut}$ entries of the matrix $\underline{\mathbf{Y}}(k)$. The mean square error (or the square error, since a divide by $N_{ap} \cdot N_{ut}$ is omitted) is then equal to the sum of all $N_{ap} \cdot N_{ut}$ squared values.

[0327] The MMSE computation is performed for each designated subband to obtain the correction factors $\hat{\underline{\mathbf{K}}}_{ap}(k)$ and $\hat{\underline{\mathbf{K}}}_{ut}(k)$ for that subband. The MMSE computation for one subband is described below. For simplicity, the subband index, k, is omitted in the following description. Also for simplicity, the elements of the downlink channel response estimate $\hat{\underline{\mathbf{H}}}_{dn}^{T}$ are denoted as $\{a_{ji}\}$, the elements of the uplink channel response estimate $\hat{\underline{\mathbf{H}}}_{up}(k)$ are denoted as $\{b_{ij}\}$, the diagonal elements of the matrix $\hat{\underline{\mathbf{K}}}_{ap}$ are denoted as $\{u_i\}$, and the diagonal elements of the matrix $\hat{\underline{\mathbf{K}}}_{ut}$ are denoted as $\{v_j\}$, where $i = \{1 \ldots N_{ap}\}$ and $j = \{1 \ldots N_{ut}\}$.

[0328] The mean square error may be rewritten from equation (34), as follows:

$$\text{MSE} = \sum_{j=1}^{N_{ut}} \sum_{i=1}^{N_{ap}} | a_{ij} u_i - b_{ij} v_j |^2 \quad , \qquad \text{Eq (35)}$$

again subject to the constraint $u_1 = 1$. The minimum mean square error may be obtained by taking the partial derivatives of equation (35) with respect to u and v and setting the partial derivatives to zero. The results of these operations are the following equation sets:

$$\sum_{j=1}^{N_{ut}} (a_{ij} u_i - b_{ij} v_j) \cdot a_{ij}^{*} = 0 \quad , \text{for } i \in \{2 \ \ldots \ N_{ap}\} , \text{and} \qquad \text{Eq (36a)}$$

$$\sum_{i=1}^{N_{ap}} (a_{ij} u_i - b_{ij} v_j) \cdot b_{ij}^{*} = 0 \quad , \text{for } j \in \{1 \ \ldots \ N_{ut}\} . \qquad \text{Eq (36b)}$$

In equation (36a), $u_1 = 1$ so there is no partial derivative for this case, and the index i runs from 2 through N_{ap}.

[0329] The set of $(N_{ap} + N_{ut} - 1)$ equations in equation sets (36a) and (36b) may be more conveniently expressed in matrix form, as follows:

$$\underline{\mathbf{A}}\underline{\mathbf{y}} = \underline{\mathbf{z}} \quad , \qquad \text{Eq (37)}$$

where

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$$\underline{\mathbf{A}} = \begin{bmatrix} \sum_{j=1}^{N_{ut}} |a_{2j}|^2 & 0 & \cdots & 0 & -b_{21}a_{21}^* & \cdots & -b_{2N_{ap}}a_{2N_{ut}}^* \\ 0 & \sum_{j=1}^{N_{ut}} |a_{3j}|^2 & 0 & \cdots & \cdots & \cdots & \cdots \\ \cdots & 0 & \cdots & 0 & & & \\ 0 & \cdots & 0 & \sum_{j=1}^{N_{ut}} |a_{N_{ap}j}|^2 & -b_{N_{ap}1}a_{N_{ap}1}^* & & -b_{N_{ap}N_{ut}}a_{N_{ap}N_{ut}}^* \\ -a_{21}b_{21}^* & \cdots & & -a_{N_{ap}1}b_{N_{ap}1}^* & \sum_{i=1}^{N_{ap}} |b_{i1}|^2 & 0 \cdots & 0 \\ \cdots & \cdots & & & 0 & \sum_{i=1}^{N_{ap}} |b_{i2}|^2 \; 0 & \cdots \\ & & & & \cdots & 0 \cdots & 0 \\ -a_{2N_{ut}}b_{2N_{ut}}^* & \cdots & & -a_{N_{ap}N_{ut}}b_{N_{ap}N_{ut}}^* & 0 & \cdots 0 & \sum_{i=1}^{N_{ap}} |b_{iN_{ut}}|^2 \end{bmatrix}$$

$$\underline{\mathbf{y}} = \begin{bmatrix} u_2 \\ u_3 \\ \cdots \\ u_{N_{ap}} \\ v_1 \\ v_2 \\ \cdots \\ v_{N_{ut}} \end{bmatrix} \text{ and } \underline{\mathbf{z}} = \begin{bmatrix} 0 \\ 0 \\ \cdots \\ 0 \\ a_{11}b_{11}^* \\ a_{12}b_{12}^* \\ \cdots \\ a_{1N_{ut}}b_{1N_{ut}}^* \end{bmatrix}.$$

[0330] The matrix $\underline{\mathbf{A}}$ includes (N_{ap}+N_{ut}-1) rows, with the first N_{ap}-1 rows corresponding to the N_{ap}-1 equations from equation set (36a) and the last N_{ut} rows corresponding to the N_{ut} equations from equation set (36b). In particular, the first row of the matrix $\underline{\mathbf{A}}$ is generated from equation set (36a) with i=2 , the second row is generated with i=3 , and so on. The N_{ap} -th row of the matrix $\underline{\mathbf{A}}$ is generated from equation set (36b) with j=1, and so on, and the last row is generated with $j = N_{ut}$. As shown above, the entries of the matrix $\underline{\mathbf{A}}$ and the entries of the vector $\underline{\mathbf{z}}$ may be obtained based on the entries in the matrices $\hat{\underline{\mathbf{H}}}_{dn}^{T}$ and $\hat{\underline{\mathbf{H}}}_{up}$.

[0331] The correction factors are included in the vector $\underline{\mathbf{y}}$, which may be obtained as:

$$\underline{\mathbf{y}} = \underline{\mathbf{A}}^{-1}\underline{\mathbf{z}} \quad . \qquad \text{Eq (38)}$$

[0332] The results of the MMSE computation are correction matrices $\hat{\underline{\mathbf{K}}}_{ap}$ and $\hat{\underline{\mathbf{K}}}_{ut}$ that minimize the mean square error in the calibrated downlink and uplink channel responses, as shown in equation (34). Since the matrices $\hat{\underline{\mathbf{K}}}_{ap}$ and $\hat{\underline{\mathbf{K}}}_{ut}$ are obtained based on the downlink and uplink channel response estimates, $\hat{\underline{\mathbf{H}}}_{dn}$ and $\hat{\underline{\mathbf{H}}}_{up}$, the quality of the correction matrices $\hat{\underline{\mathbf{K}}}_{ap}$ and $\hat{\underline{\mathbf{K}}}_{ut}$ are thus dependent on the quality of the channel estimates $\hat{\underline{\mathbf{H}}}_{dn}$ and $\hat{\underline{\mathbf{H}}}_{up}$. The MIMO pilot may be averaged at the receiver to obtain more accurate estimates for $\hat{\underline{\mathbf{H}}}_{dn}$ and $\hat{\underline{\mathbf{H}}}_{up}$.

[0333] The correction matrices, $\hat{\underline{\mathbf{K}}}_{ap}$ and $\hat{\underline{\mathbf{K}}}_{ut}$, obtained based on the MMSE computation are generally better than the correction matrices obtained based on the matrix-ratio computation. This is especially true when some of the channel

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gains are small and measurement noise can greatly degrade the channel gains.

3. Post Computation

[0334] A pair of correction vectors, $\hat{\underline{k}}_{ap}(k)$ and $\hat{\underline{k}}_{ut}(k)$, may be determined for each of the data subbands. Since adjacent subbands are likely to be correlated, the computation may be simplified. For example, the computation may be performed for every *n*-th subband instead of each subband, where *n* may be determined by the expected response of the transmit/receive chains. If the calibration is performed for fewer than all of the data and pilot subbands, then the correction factors for the "uncalibrated" subbands may be obtained by interpolating the correction factors obtained for the "calibrated" subbands.

[0335] Various other calibration schemes may also be used to derive the correction vectors, $\hat{\underline{k}}_{ap}(k)$ and $\hat{\underline{k}}_{ut}(k)$, for the access point and the user terminal, respectively. However, the scheme described above allows "compatible" correction vectors to be derived for the access point when the calibration is performed by different user terminals.

[0336] After the derivation, the user terminal sends the correction vectors $\hat{\underline{k}}_{ap}(k)$ for all data subbands back to the access point. If the access point has already been calibrated (e.g., by other user terminals), then the current correction vectors are updated with the newly received correction vectors. Thus, if the access point uses correction vectors $\hat{\underline{k}}_{ap1}(k)$ to transmit the MIMO pilot from which the user terminal determines new correction vectors $\hat{\underline{k}}_{ap2}(k)$, then the updated correction vectors are the product of the current and new correction vectors, i.e., $\hat{\underline{k}}_{ap3}(k) = \hat{\underline{k}}_{ap1}(k) \cdot \hat{\underline{k}}_{ap2}(k)$, where the multiplication is element-by-element. The updated correction vectors $\hat{\underline{k}}_{ap3}(k)$ may then be used by the access point until they are updated again.

[0337] The correction vectors $\hat{\underline{k}}_{ap1}(k)$ and $\hat{\underline{k}}_{ap2}(k)$ may be derived by the same or different user terminals. In one embodiment, the updated correction vectors are defined as $\hat{\underline{k}}_{ap3}(k) = \hat{\underline{k}}_{ap1}(k) \cdot \hat{\underline{k}}_{ap2}(k)$, where the multiplication is element-by-element. In another embodiment, the updated correction vectors may be redefined as $\hat{\underline{k}}_{ap3}(k) = \hat{\underline{k}}_{ap1}(k) \cdot \hat{\underline{k}}_{ap2}^{\alpha}(k)$, where α is a factor used to provide weighted averaging (e.g., $0<\alpha<1$). If the calibration updates are infrequent, then α close to one might perform best. If the calibration updates are frequent but noisy, then a smaller value for α is better. The updated correction vectors $\hat{\underline{k}}_{ap3}(k)$ may then be used by the access point until they are updated again.

[0338] The access point and user terminal use their respective correction vectors $\hat{\underline{k}}_{ap}(k)$ and $\hat{\underline{k}}_{ut}(k)$, or the corresponding correction matrices $\hat{\underline{K}}_{ap}(k)$ and $\hat{\underline{K}}_{ut}(k)$, for $k \in K$, to scale the modulation symbols prior to transmission, as described below. The calibrated downlink and uplink channels that the user terminal and access point observe are shown in equation (27).

VII. Spatial Processing

[0339] The spatial processing at the access point and user terminal may be simplified for a TDD system, after calibration has been performed to account for the difference in the transmit/receive chains. As noted above, the calibrated downlink channel response is $\underline{H}_{cdn}(k)=\underline{H}_{dn}(k)\hat{\underline{K}}_{ap}(k)$. The calibrated uplink channel response is $\underline{H}_{cup}(k)=\underline{H}_{up}(k)\hat{\underline{K}}_{ut}(k)\approx(\underline{H}_{dn}(k)\hat{\underline{K}}_{ap}(k))^{T}$.

1. Uplink Spatial Processing

[0340] Singular value decomposition of the calibrated uplink channel response matrix, $\underline{H}_{cup}(k)$, may be expressed as:

$$\underline{H}_{cup}(k) = \underline{U}_{ap}(k)\underline{\Sigma}(k)\underline{V}_{ut}^{H}(k) \quad \text{, for } k \in K \text{,} \qquad \text{Eq (39)}$$

where $\underline{U}_{ap}(k)$ is an $(N_{ap} \times N_{ap})$ unitary matrix of left eigenvectors of $\underline{H}_{cup}(k)$;
$\underline{\Sigma}(k)$ is an $(N_{ap} \times N_{ut})$ diagonal matrix of singular values of $\underline{H}_{cup}(k)$, and
$\underline{V}_{ut}(k)$ is an $(N_{ut} \times N_{ut})$ unitary matrix of right eigenvectors of $\underline{H}_{cup}(k)$.

[0341] Correspondingly, singular value decomposition of the calibrated downlink channel response matrix, $\underline{H}_{cdn}(k)$, may be expressed as:

$$\underline{H}_{cdn}(k) = \underline{V}_{ut}^{*}(k)\underline{\Sigma}(k)\underline{U}_{ap}^{T}(k) \quad \text{, for } k \in K \text{.} \qquad \text{Eq (40)}$$

The matrices $\underline{\mathbf{V}}_{ut}^{*}(k)$ and $\underline{\mathbf{U}}_{ap}^{*}(k)$ are also matrices of left and right eigenvectors, respectively, of $\underline{\mathbf{H}}_{cdn}(k)$. As shown in equations (39) and (40) and based on the above description, the matrices of left and right eigenvectors for one link are the complex conjugate of the matrices of right and left eigenvectors, respectively, for the other link. The matrices $\underline{\mathbf{V}}_{ut}(k)$, $\underline{\mathbf{V}}_{ut}^{*}(k)$, $\underline{\mathbf{V}}_{ut}^{T}(k)$, and $\underline{\mathbf{V}}_{ut}^{H}(k)$ are different forms of the matrix $\underline{\mathbf{V}}_{ut}(k)$, and the matrices $\underline{\mathbf{U}}_{ap}(k)$, $\underline{\mathbf{U}}_{ap}^{*}(k)$, $\underline{\mathbf{U}}_{ap}^{T}(k)$, and $\underline{\mathbf{U}}_{ap}^{H}(k)$ are also different forms of the matrix $\underline{\mathbf{U}}_{ap}(k)$. For simplicity, reference to the matrices $\underline{\mathbf{U}}_{ap}(k)$ and $\underline{\mathbf{V}}_{ut}(k)$ in the following description may also refer to their various other forms. The matrices $\underline{\mathbf{U}}_{ap}(k)$ and $\underline{\mathbf{V}}_{ut}(k)$ are used by the access point and user terminal, respectively, for spatial processing and are denoted as such by their subscripts. The eigenvectors are also often referred to as "steering" vectors.

[0342] The user terminal can estimate the calibrated downlink channel response based on the MIMO pilot sent by the access point. The user terminal can then perform the singular value decomposition of the calibrated downlink channel response estimate $\hat{\underline{\mathbf{H}}}_{cdn}(k)$, for $k \in K$, to obtain the diagonal matrix $\hat{\underline{\Sigma}}(k)$ and the matrix $\hat{\underline{\mathbf{V}}}_{ut}^{*}(k)$ of left eigenvectors of $\hat{\underline{\mathbf{H}}}_{cdn}(k)$. This singular value decomposition may be given as $\hat{\underline{\mathbf{H}}}_{cdn}(k) = \hat{\underline{\mathbf{V}}}_{ut}^{*}(k)\hat{\underline{\Sigma}}(k)\hat{\underline{\mathbf{U}}}_{ap}^{T}(k)$, where the hat ("^") above each matrix indicates that it is an estimate of the actual matrix.

[0343] Similarly, the access point can estimate the calibrated uplink channel response based on a MIMO pilot sent by the user terminal. The access point may then perform singular value decomposition for the calibrated uplink channel response estimate $\hat{\underline{\mathbf{H}}}_{cup}(k)$, for $k \in K$, to obtain the diagonal matrix $\hat{\underline{\Sigma}}(k)$ and the matrix $\hat{\underline{\mathbf{U}}}_{ap}(k)$ of left eigenvectors of $\hat{\underline{\mathbf{H}}}_{cup}(k)$. This singular value decomposition may be given as $\hat{\underline{\mathbf{H}}}_{cup}(k) = \hat{\underline{\mathbf{U}}}_{ap}(k)\hat{\underline{\Sigma}}(k)\hat{\underline{\mathbf{V}}}_{ut}^{H}(k)$.

[0344] An $(N_{ut} \times N_{ut})$ matrix $\underline{\mathbf{F}}_{ut}(k)$ may be defined as:

$$\underline{\mathbf{F}}_{ut}(k) = \hat{\underline{\mathbf{K}}}_{ut}(k)\hat{\underline{\mathbf{V}}}_{ut}(k) \quad \text{, for } k \in K. \qquad \text{Eq (41)}$$

While it is active, the user terminal keeps a running estimate of the calibrated downlink channel $\hat{\underline{\mathbf{H}}}_{cdn}(k)$ and the matrices $\hat{\underline{\mathbf{V}}}_{ut}(k)$ of left eigenvectors of $\hat{\underline{\mathbf{H}}}_{cdn}(k)$, which are used to update the matrix $\underline{\mathbf{F}}_{ut}(k)$.

[0345] The user terminal uses the matrix $\underline{\mathbf{F}}_{ut}(k)$ for the spatial processing for the beam-steering and spatial multiplexing modes. For the spatial multiplexing mode, the transmit vector $\underline{\mathbf{x}}_{up}(k)$ for each subband may be expressed as:

$$\underline{\mathbf{x}}_{up}(k) = \underline{\mathbf{F}}_{ut}(k)\underline{\mathbf{s}}_{up}(k) \quad \text{, for } k \in K, \qquad \text{Eq (42)}$$

where $\underline{\mathbf{s}}_{up}(k)$ is a data vector with up to N_s symbols to be transmitted on the N_s eigenmodes of subband k;
$\underline{\mathbf{F}}_{ut}(k)$ substitutes for $\underline{\mathbf{V}}(k)$ in equation (15), and the signal scaling by $\underline{\mathbf{G}}(k)$ to achieve channel inversion is omitted in equation (42) for simplicity; and
$\underline{\mathbf{x}}_{up}(k)$ is the transmit vector for the uplink for subband k.

[0346] At the access point, the received vector $\underline{\mathbf{r}}_{up}(k)$ for the uplink transmission may be expressed as:

$$\begin{aligned}
\underline{\mathbf{r}}_{up}(k) &= \underline{\mathbf{H}}_{up}(k)\underline{\mathbf{x}}_{up}(k) + \underline{\mathbf{n}}_{up}(k) \qquad \text{, for } k \in K, \quad \text{Eq (43)} \\
&= \underline{\mathbf{H}}_{up}(k)\hat{\underline{\mathbf{K}}}_{ut}(k)\hat{\underline{\mathbf{V}}}_{ut}(k)\underline{\mathbf{s}}_{up}(k) + \underline{\mathbf{n}}_{up}(k) \\
&\approx \hat{\underline{\mathbf{H}}}_{cup}(k)\hat{\underline{\mathbf{V}}}_{ut}(k)\underline{\mathbf{s}}_{up}(k) + \underline{\mathbf{n}}_{up}(k) \\
&= \hat{\underline{\mathbf{U}}}_{ap}(k)\hat{\underline{\Sigma}}(k)\hat{\underline{\mathbf{V}}}_{ut}^{H}(k)\hat{\underline{\mathbf{V}}}_{ut}(k)\underline{\mathbf{s}}_{up}(k) + \underline{\mathbf{n}}_{up}(k) \\
&= \hat{\underline{\mathbf{U}}}_{ap}(k)\hat{\underline{\Sigma}}(k)\underline{\mathbf{s}}_{up}(k) + \underline{\mathbf{n}}_{up}(k)
\end{aligned}$$

where $\underline{\mathbf{r}}_{up}(k)$ is the received vector for the uplink subband k; and
$\underline{\mathbf{n}}_{up}(k)$ is additive white Gaussian noise (AWGN) for subband k.

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Equation (43) uses the following relationships: $\underline{H}_{up}(k)\hat{\underline{K}}_{ut}(k)=\underline{H}_{cup}(k)\approx\hat{\underline{H}}_{cup}(k)$ and $\hat{\underline{H}}_{cup}(k)=\hat{\underline{U}}_{ap}(k)\hat{\underline{\Sigma}}(k)\hat{\underline{V}}_{ut}^{H}(k)$. As shown in equation (43), at the access point, the received uplink transmission is transformed by $\hat{\underline{U}}_{ap}(k)\hat{\underline{\Sigma}}(k)$, which is the matrix $\hat{\underline{U}}_{ap}(k)$ of left eigenvectors of $\hat{\underline{H}}_{cup}(k)$ scaled by the diagonal matrix $\hat{\underline{\Sigma}}(k)$ of singular values.

[0347] The user terminal transmits a steered reference on the uplink using the matrix $\underline{F}_{ut}(k)$. The steered reference is a pilot transmission on one wideband eigenmode using either beam-steering or beam-forming, and is described in detail below. At the access point, the received uplink steered reference (in the absence of noise) is approximately $\hat{\underline{U}}_{ap}(k)\hat{\underline{\Sigma}}(k)$. The access point can thus obtain an estimate of the unitary matrix $\hat{\underline{U}}_{ap}(k)$ and diagonal matrix $\hat{\underline{\Sigma}}(k)$ based on the steered reference sent by the user terminal. Various estimation techniques may be used to obtain the estimate of the unitary and diagonal matrices.

[0348] In one embodiment, to obtain an estimate of $\hat{\underline{U}}_{ap}(k)$, the received vector $\underline{r}_m(k)$ for the steered reference for subband k of wideband eigenmode m is first multiplied with the complex conjugate of a pilot OFDM symbol, $p^*(k)$, sent for the steered reference. The generation of the steered reference and the pilot OFDM symbol are described in detail below. The result is then integrated over multiple received steered reference symbols for each wideband eigenmode to obtain an estimate of $\hat{\underline{u}}_m(k)\sigma_m(k)$, which is a scaled left eigenvector of $\hat{\underline{H}}_{cup}(k)$ for wideband eigenmode m. Since eigenvectors have unit power, the singular values (or $\sigma_m(k)$) in $\hat{\underline{\Sigma}}(k)$ may be estimated based on the received power of the steered reference, which can be measured for each subband of each wideband eigenmode.

[0349] In another embodiment, an MMSE technique is used to obtain an estimate of $\hat{\underline{u}}_m(k)$ based on the received vector $\underline{r}_m(k)$ for the steered reference.

[0350] The steered reference may be sent for one wideband eigenmode in any given symbol period, and may in turn be used to obtain an estimate of one eigenvector for each subband of that wideband eigenmode. Thus, the receiver is able to obtain an estimate of one eigenvector in a unitary matrix for any given symbol period. Since estimates of multiple eigenvectors for the unitary matrix are obtained over different symbol periods, and due to noise and other sources of degradation in the transmission path, the estimated eigenvectors for the unitary matrix are not likely be orthogonal. If the estimated eigenvectors are thereafter used for spatial processing of data transmission on the other link, then any errors in orthogonality in these estimated eigenvectors would result in cross-talk among the eigenmodes, which may degrade performance.

[0351] In an embodiment, the estimated eigenvectors for each unitary matrix are forced to be orthogonal to each other. The orthogonalization of the eigenvectors may be achieved using various techniques such as QR factorization, minimum square error computation, polar decomposition, and so on. QR factorization decomposes a matrix $\underline{M}^T$ (with non-orthogonal columns) into an orthogonal matrix $\underline{Q}_F$ and an upper triangle matrix $\underline{R}_F$. The matrix $\underline{Q}_F$ forms an orthogonal basis for the columns of $\underline{M}^T$. The diagonal elements of $\underline{R}_F$ give the length of the components of the columns of $\underline{M}^T$ in the directions of the respective columns of $\underline{Q}_F$. The matrix $\underline{Q}_F$ may be used for spatial processing on the downlink. The matrices $\underline{Q}_F$ and $\underline{R}_F$ may be used to derive an enhanced matched filter matrix for the uplink. The QR factorization may be performed by various methods including a Gram-Schmidt procedure, a householder transformation, and so on.

[0352] Other techniques to estimate the unitary and diagonal matrices based on the steered reference may also be used, and this is within the scope of the invention.

[0353] The access point can thus estimate both $\hat{\underline{U}}_{ap}(k)$ and $\hat{\underline{\Sigma}}(k)$ based on the steered reference sent by the user terminal, without having to perform singular value decomposition on $\hat{\underline{H}}_{cup}(k)$.

[0354] A normalized matched filter matrix $\underline{M}_{ap}(k)$ for the uplink transmission from the user terminal may be expressed as:

$$\underline{M}_{ap}(k)=\hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{U}}_{ap}^{H}(k) \quad \text{, for } k\in K. \qquad \text{Eq (44)}$$

The matched filtering at the access point for the uplink transmission may then be expressed as:

$$\begin{aligned}\hat{\underline{s}}_{up}(k) &= \underline{M}_{ap}(k)\underline{r}_{up}(k)\\ &= \hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{U}}_{ap}^{H}(k)(\hat{\underline{U}}_{ap}(k)\hat{\underline{\Sigma}}(k)\underline{s}_{up}(k)+\underline{n}_{up}(k)) \quad \text{, for } k\in K, \quad \text{Eq (45)}\\ &= \underline{s}_{up}(k)+\tilde{\underline{n}}_{up}(k)\end{aligned}$$

where $\hat{\underline{s}}_{up}(k)$ is an estimate of the vector of modulation symbols $\underline{s}_{up}(k)$ transmitted by the user terminal for the spatial multiplexing mode. For the beam-steering mode, only one row of the matrix $\underline{M}_{ap}(k)$ is used to provide one symbol estimate

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$\hat{\underline{s}}(k)$ for the eigenmode used for data transmission.

2. Downlink Spatial Processing

[0355] For the downlink, the access point uses an $(N_{ap} \times N_{ap})$ matrix $\underline{F}_{ap}(k)$ for spatial processing. This matrix may be expressed as:

$$\underline{F}_{ap}(k) = \hat{\underline{K}}_{ap}(k)\hat{\underline{U}}_{ap}^{*}(k) \quad , \text{for } k \in K . \qquad \text{Eq (46)}$$

The correction matrix $\hat{\underline{K}}_{ap}(k)$ is derived by the user terminal and sent back to the access point during calibration. The matrix $\hat{\underline{U}}_{ap}(k)$ may be obtained based on the steered reference sent on the uplink by the user terminal.

[0356] For the spatial multiplexing mode, the transmit vector $\underline{x}_{dn}(k)$ for the downlink for each data subband may be expressed as:

$$\underline{x}_{dn}(k) = \underline{F}_{ap}(k)\underline{s}_{dn}(k) \quad , \text{for } k \in K , \qquad \text{Eq (47)}$$

where $\underline{x}_{dn}(k)$ is the transmit vector, $\underline{s}_{dn}(k)$ is the data vector for the downlink, and the signal scaling by $\underline{G}(k)$ to achieve channel inversion is again omitted for simplicity.

[0357] At the user terminal, the received vector $\underline{r}_{dn}(k)$ for the downlink transmission may be expressed as:

$$\begin{aligned}
\underline{r}_{dn}(k) &= \underline{H}_{dn}(k)\underline{x}_{dn}(k) + \underline{n}_{dn}(k) \\
&= \underline{H}_{dn}(k)\hat{\underline{K}}_{ap}(k)\hat{\underline{U}}_{ap}^{*}(k)\underline{s}_{dn}(k) + \underline{n}_{dn}(k) \\
&\approx \hat{\underline{H}}_{cdn}(k)\hat{\underline{U}}_{ap}^{*}(k)\underline{s}_{dn}(k) + \underline{n}_{dn}(k) \\
&= \hat{\underline{V}}_{ut}^{*}(k)\hat{\underline{\Sigma}}(k)\hat{\underline{U}}_{ap}^{T}(k)\hat{\underline{U}}_{ap}^{*}(k)\underline{s}_{dn}(k) + \underline{n}_{dn}(k)) \\
&= \hat{\underline{V}}_{ut}^{*}(k)\hat{\underline{\Sigma}}(k)\underline{s}_{dn}(k) + \underline{n}_{dn}(k) \qquad , \text{for } k \in K . \quad \text{Eq (48)}
\end{aligned}$$

As shown in equation (48), at the user terminal, the received downlink transmission is transformed by $\hat{\underline{V}}_{ut}^{*}(k)\hat{\underline{\Sigma}}(k)$, which is the matrix $\hat{\underline{V}}_{ut}(k)$ of left eigenvectors of $\hat{\underline{H}}_{cdn}(k)$ scaled by the diagonal matrix $\hat{\underline{\Sigma}}(k)$ of singular values.

[0358] A normalized matched filter matrix $\underline{M}_{ut}(k)$ for the downlink transmission from the access point may be expressed as:

$$\underline{M}_{ut}(k) = \hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{V}}_{ut}^{T}(k) \quad , \text{for } k \in K . \qquad \text{Eq (49)}$$

The diagonal matrix $\hat{\underline{\Sigma}}(k)$ and matrix $\hat{\underline{V}}_{ut}(k)$ of left eigenvectors can be derived by the user terminal by performing singular value decomposition on the calibrated downlink channel response estimate $\hat{\underline{H}}_{cdn}(k)$, as described above.

[0359] The matched filtering at the user terminal for the downlink transmission may then be expressed as:

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$$\begin{aligned}\hat{\underline{s}}_{dn}(k) &= \underline{M}_{ul}(k)\underline{r}_{dn}(k) \\ &= \hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{V}}_{ul}^{T}(k)(\hat{\underline{V}}_{ul}^{*}(k)\hat{\underline{\Sigma}}(k)\underline{s}_{dn}(k)+\underline{n}_{dn}(k)) \quad \text{, for } k \in K \text{.} \quad \text{Eq (50)} \\ &= \underline{s}_{dn}(k)+\tilde{\underline{n}}_{dn}(k)\end{aligned}$$

3. Access Point and User Terminal Spatial Processing

[0360] Because of the reciprocal channel for the TDD system and the calibration, the spatial processing at both the access point and the user terminal may be simplified. Table 32 summarizes the spatial processing at the access point and user terminal for data transmission and reception.

Table 32

	Uplink	Downlink
User Terminal	Transmit: $\underline{x}_{up}(k) = \hat{\underline{K}}_{ut}(k)\hat{\underline{V}}_{ut}(k)\underline{s}_{up}(k)$	Receive : $\hat{\underline{s}}_{dn}(k) = \hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{V}}_{ut}^{T}(k)\underline{r}_{dn}(k)$
Access Point	Receive: $\hat{\underline{s}}_{up}(k) = \hat{\underline{\Sigma}}^{-1}(k)\hat{\underline{U}}_{ap}^{H}(k)\underline{r}_{up}(k)$	Transmit: $\underline{x}_{dn}(k) = \hat{\underline{K}}_{ap}(k)\hat{\underline{U}}_{ap}^{*}(k)\underline{s}_{dn}(k)$

The spatial processing for data reception is also commonly referred to as matched filtering.

[0361] Because of the reciprocal channel, $\hat{\underline{V}}_{ut}(k)$ is both the matrix of right eigenvectors of $\hat{\underline{H}}_{cup}(k)$ (to transmit) and left eigenvectors of $\hat{\underline{H}}_{cdn}(k)$ (to receive) for the user terminal. Similarly, $\hat{\underline{U}}_{ap}(k)$ is both the matrix of right eigenvectors of $\hat{\underline{H}}_{cdn}(k)$ (to transmit) and left eigenvectors of $\hat{\underline{H}}_{cup}(k)$ (to receive) for the access point. The singular value decomposition only needs to be performed by the user terminal for the calibrated downlink channel response estimate $\hat{\underline{H}}_{cdn}(k)$ to obtain $\hat{\underline{V}}_{ut}(k)$ and $\hat{\underline{\Sigma}}(k)$. The access point can derive $\hat{\underline{U}}_{ap}(k)$ and $\hat{\underline{\Sigma}}(k)$ based on the steered reference sent by the user terminal and does not need to perform the singular value decomposition on the uplink channel response estimate $\hat{\underline{H}}_{cup}(k)$. The access point and user terminal may have different versions of the matrix $\hat{\underline{\Sigma}}(k)$ due to the different means used by the access point and user terminal to derive $\hat{\underline{\Sigma}}(k)$. Moreover, the matrix $\hat{\underline{U}}_{ap}(k)$ derived by the access point based on the steered reference is typically different from the matrix $\hat{\underline{U}}_{ap}(k)$ derived by the user terminal using singular value decomposition. For simplicity, these differences are not shown in the above derivation.

4. Beam-Steering

[0362] For certain channel conditions, it is better to transmit data on only one wideband eigenmode - typically the best or principal wideband eigenmode. This may be the case if the received SNRs for all other wideband eigenmodes are sufficiently poor so that improved performance is achieved by using all of the available transmit power on the principal wideband eigenmode.

[0363] Data transmission on one wideband eigenmode may be achieved using either beam-forming or beam-steering. For beam-forming, the modulation symbols are spatially processed with the eigenvectors $\hat{\underline{v}}_{ut,1}(k)$ or $\hat{\underline{u}}_{ap,1}(k)$, for $k \in K$, for the principal wideband eigenmode (i.e., the first column of $\hat{\underline{V}}_{ut}(k)$ or $\hat{\underline{U}}_{ap}(k)$, after the ordering). For beam-steering, the modulation symbols are spatially processed with a set of "normalized" (or "saturated") eigenvectors $\bar{\underline{v}}_{ut}(k)$ or $\bar{\underline{u}}_{ap}(k)$, for $k \in K$, for the principal wideband eigenmode. For clarity, beam-steering is described below for the uplink.

[0364] For the uplink, the elements of each eigenvector $\hat{\underline{v}}_{ut,1}(k)$, for $k \in K$, for the principal wideband eigenmode may have different magnitudes. Thus, the preconditioned symbols for each subband, which are obtained by multiplying the modulation symbol for subband k with the elements of the eigenvector $\hat{\underline{v}}_{ut,1}(k)$ for subband k, may then have different magnitudes. Consequently, the per-antenna transmit vectors, each of which includes the preconditioned symbols for all data subbands for a given transmit antenna, may have different magnitudes. If the transmit power for each transmit antenna is limited (e.g., because of limitations of power amplifiers), then beam-forming may not fully use the total power available for each antenna.

[0365]] Beam-steering uses only the phase information from the eigenvectors $\hat{\underline{v}}_{ut,1}(k)$, for $k \in K$, for the principal wideband eigenmode and normalizes each eigenvector such that all elements in the eigenvector have equal magnitudes.

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The normalized eigenvector $\underline{\tilde{\mathbf{v}}}_{ut}(k)$ for subband k may be expressed as:

$$\underline{\tilde{\mathbf{v}}}_{ut}(k) = [Ae^{j\theta_1(k)} \; Ae^{j\theta_2(k)} \; \ldots \; Ae^{j\theta_{N_{ut}}(k)}]^T \quad , \qquad \text{Eq (51)}$$

where A is a constant (e.g., A = 1); and
$\theta_i(k)$ is the phase for subband k of transmit antenna i, which is given as:

$$\theta_i(k) = \angle \hat{v}_{ut,1,i}(k) = \tan^{-1}\left(\frac{\mathrm{Im}\{\hat{v}_{ut,1,i}(k)\}}{\mathrm{Re}\{\hat{v}_{ut,1,i}(k)\}}\right) . \qquad \text{Eq (52)}$$

As shown in equation (52), the phase of each element in the vector $\underline{\tilde{\mathbf{v}}}_{ut}(k)$ is obtained from the corresponding element of the eigenvector $\underline{\hat{\mathbf{v}}}_{ut,1}(k)$ (i.e., $\theta_i(k)$ is obtained from $\underline{\hat{v}}_{ut,1,i}(k)$, where $\underline{\hat{\mathbf{v}}}_{ut,1}(k) = [\underline{\hat{v}}_{ut,1,1}(k) \; \underline{\hat{v}}_{ut,1,2}(k) \; \ldots \; \underline{\hat{v}}_{ut,1,Nut}(k)]^T$).

5. Uplink Beam-Steering

[0366] The spatial processing by the user terminal for beam-steering on the uplink may be expressed as:

$$\underline{\tilde{\mathbf{x}}}_{up}(k) = \underline{\hat{\mathbf{K}}}_{ut}\,\underline{\tilde{\mathbf{v}}}_{ut}(k)s_{up}(k) \quad , \text{for } k \in K , \qquad \text{Eq (53)}$$

where $s_{up}(k)$ is the modulation symbol to be transmitted on subband k; and
$\underline{\tilde{\mathbf{x}}}_{up}(k)$ is the transmit vector for subband k for beam-steering.
As shown in equation (53), the N_{ut} elements of the normalized steering vector $\underline{\tilde{\mathbf{v}}}_{ut}(k)$ for each subband have equal magnitude but possibly different phases. The beam-steering thus generates one transmit vector $\underline{\tilde{\mathbf{x}}}_{up}(k)$ for each subband, with the N_{ut} elements of $\underline{\tilde{\mathbf{x}}}_{up}(k)$ having the same magnitude but possibly different phases.

[0367] The received uplink transmission at the access point for beam-steering may be expressed as:

$$\begin{aligned}\underline{\tilde{\mathbf{r}}}_{up}(k) &= \underline{\mathbf{H}}_{up}(k)\underline{\tilde{\mathbf{x}}}_{up}(k) + \underline{\mathbf{n}}_{up}(k) \qquad \text{, for } k \in K , \qquad \text{Eq (54)} \\ &= \underline{\mathbf{H}}_{up}(k)\underline{\hat{\mathbf{K}}}_{ut}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)s_{up}(k) + \underline{\mathbf{n}}_{up}(k) \\ &= \underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)s_{up}(k) + \underline{\mathbf{n}}_{up}(k)\end{aligned}$$

where $\underline{\tilde{\mathbf{r}}}_{up}(k)$ is the received vector for the uplink for subband k for beam-steering.

[0368] A matched filter row vector $\underline{\tilde{\mathbf{m}}}_{ap}(k)$ for the uplink transmission using beam-steering may be expressed as:

$$\underline{\tilde{\mathbf{m}}}_{ap}(k) = (\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k))^H , \text{ for } k \in K . \qquad \text{Eq (55)}$$

The matched filter vector $\underline{\tilde{\mathbf{m}}}_{ap}(k)$ may be obtained as described below. The spatial processing (or matched filtering) at the access point for the received uplink transmission with beam-steering may be expressed as:

$$\begin{aligned}\hat{s}_{up}(k) &= \tilde{\lambda}_{up}^{-1}(k)\underline{\tilde{\mathbf{m}}}_{ap}(k)\underline{\tilde{\mathbf{r}}}_{up}(k) \\ &= \tilde{\lambda}_{up}^{-1}(k)(\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k))^H(\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)s_{up}(k) + \underline{\mathbf{n}}_{up}(k)) \text{ , for } k \in K , \quad \text{Eq (56)} \\ &= s_{up}(k) + \tilde{n}_{up}(k)\end{aligned}$$

where $\tilde{\lambda}_{up}(k) = (\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k))^H(\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k))$ (i.e., $\tilde{\lambda}_{up}(k)$ is the inner product of

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$\underline{\tilde{m}}_{ap}(k)$ and its conjugate transpose),
$\hat{s}_{up}(k)$ is an estimate of the modulation symbol $s_{up}(k)$ transmitted by the user terminal on the uplink, and
$\hat{n}_{up}(k)$ is the post-processed noise.

6. Downlink Beam-Steering

[0369] The spatial processing by the access point for beam-steering on the downlink may be expressed as:

$$\underline{\tilde{x}}_{dn}(k) = \underline{\hat{K}}_{ap}\underline{\tilde{u}}_{ap}(k)s_{dn}(k) \quad \text{, for } k \in K, \qquad \text{Eq (57)}$$

where $\underline{\tilde{u}}_{ap}(k)$ is the normalized eigenvector for subband k, which is generated based on the eigenvector $\underline{\hat{u}}^{*}_{ap,1}(k)$, for the principal wideband eigenmode, similar to that described above for the uplink.

[0370] A matched filter row vector $\underline{\tilde{m}}_{ut}(k)$ for the downlink transmission using beam-steering may be expressed as:

$$\underline{\tilde{m}}_{ut}(k) = (\underline{H}_{cdn}(k)\underline{\tilde{u}}_{ap}(k))^{H} \quad \text{, for } k \in K. \qquad \text{Eq (58)}$$

The spatial processing (or matched filtering) at the user terminal for the received downlink transmission may be expressed as:

$$\begin{aligned}\hat{s}_{dn}(k) &= \tilde{\lambda}^{-1}_{dn}(k)\underline{\tilde{m}}_{ut}(k)\underline{\tilde{r}}_{dn}(k) \\ &= \tilde{\lambda}^{-1}_{dn}(k)(\underline{H}_{cdn}(k)\underline{\tilde{u}}_{ap}(k))^{H}(\underline{H}_{cdn}(k)\underline{\tilde{u}}_{ap}(k)s_{up}(k) + \underline{n}_{dn}(k)), \text{ for } k \in K, \qquad \text{Eq (59)} \\ &= s_{dn}(k) + \tilde{n}_{dn}(k)\end{aligned}$$

where $\tilde{\lambda}_{dn}(k) = (\underline{H}_{cdn}(k)\underline{\tilde{u}}_{ap}(k))^{H}(\underline{H}_{cdn}(k)\underline{\tilde{u}}_{ap}(k))$ (i.e., $\tilde{\lambda}_{dn}(k)$ is the inner product of $\underline{\tilde{m}}_{ut}(k)$ and its conjugate transpose).

7. Spatial Processing with Channel Inversion

[0371] For the uplink, the transmit vector $\underline{x}_{up}(k)$ for the spatial multiplexing mode may be derived by the user terminal as:

$$\underline{x}_{up}(k) = \underline{\hat{K}}_{ut}(k)\underline{\hat{V}}_{ut}(k)\underline{G}(k)\underline{s}_{up}(k) \quad \text{, for } k \in K, \qquad \text{Eq (60)}$$

where $\underline{G}(k)$ is a diagonal matrix of gains for the channel inversion described above. Equation (60) is similar to equation (15), except that $\underline{\hat{K}}_{ut}(k)\underline{\hat{V}}_{ut}(k)$ is used in place of $\underline{V}(k)$. The elements of $\underline{\hat{K}}_{ut}(k)\underline{\hat{V}}_{ut}(k)$ are provided to multipliers 952 within beam-formers 950 in FIG. 9B.

[0372] For the uplink, the transmit vector $\underline{\tilde{x}}_{up}(k)$ for the beam-steering mode may be derived by the user terminal as:

$$\underline{\tilde{x}}_{up}(k) = \underline{\hat{K}}_{ut}(k)\underline{\tilde{v}}_{ut}(k)\tilde{g}(k)s_{up}(k) \quad \text{, for } k \in K, \qquad \text{Eq (61)}$$

where $\underline{\tilde{v}}_{ut}(k)$ is a vector with four elements having equal magnitude but phases obtained based on eigenvector $\underline{\hat{v}}_{ut,1}(k)$ for the principal eigenmode. The vector $\underline{\tilde{v}}_{ut}(k)$ may be derived similar to that shown above in equations (16) and (17). The gain $\tilde{g}(k)$ achieves channel inversion and may be derived similar to that shown above in equations (18) through (20), except that $\tilde{\lambda}_{1}(k) = \underline{\tilde{v}}^{H}_{ut}(k)\underline{\hat{H}}^{H}_{cup}(k)\underline{\hat{H}}_{cup}(k)\underline{\tilde{v}}_{ut}(k)$ is used for equation (20). The elements of $\underline{\tilde{v}}_{ut}(k)$ are provided to multipliers 1052 within beam-steering unit 1050 in FIG. 10B.

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[0373] For the downlink, the transmit vector $\underline{x}_{dn}(k)$ for the spatial multiplexing mode may be derived by the access point as:

$$\underline{x}_{dn}(k) = \hat{\underline{K}}_{ap}(k)\hat{\underline{U}}^{*}_{ap}(k)\underline{G}(k)\underline{s}_{dn}(k) \quad , \text{for } k \in K . \qquad \text{Eq (62)}$$

Equation (62) is similar to equation (15), except that $\hat{\underline{K}}_{ap}(k)\hat{\underline{U}}^{*}_{ap}(k)$ is used in place of $\underline{V}(k)$. The elements of $\hat{\underline{K}}_{ap}(k)\hat{\underline{U}}^{*}_{ap}(k)$ may be provided to multipliers 952 within beam-formers 950 in FIG. 9B.

[0374] For the downlink, the transmit vector $\tilde{\underline{x}}_{dn}(k)$ for the beam-steering mode may be derived by the access point as:

$$\tilde{\underline{x}}_{dn}(k) = \hat{\underline{K}}_{ap}(k)\tilde{\underline{u}}_{ap}(k)\tilde{g}(k)s_{dn}(k) \quad , \text{for } k \in K , \qquad \text{Eq (63)}$$

where $\tilde{\underline{u}}_{ap}(k)$ is a vector with four elements having equal magnitude but phases obtained based on eigenvector $\hat{\underline{u}}_{ap,1}(k)$ for the principal eigenmode. The gain $\tilde{g}(k)$ achieves channel inversion and may be derived in a similar manner to that shown above in equations (18) through (20), except that $\tilde{\lambda}_1(k) = \tilde{\underline{u}}^{H}_{ap}(k)\hat{\underline{H}}^{H}_{cdn}(k)\hat{\underline{H}}_{cdn}(k)\tilde{\underline{u}}_{ap}(k)$ is used for equation (20). The elements of $\tilde{\underline{u}}_{ap}(k)$ are provided to multipliers 1052 within beam-steering unit 1050 in FIG. 10B.

VIII. Pilot Structure

[0375] A pilot structure is provided for the MIMO WLAN system to allow the access points and user terminals to perform timing and frequency acquisition, channel estimation, and other functions needed for proper system operation. Table 33 lists four types of pilot and their short description for an exemplary pilot structure. Fewer, different, and/or additional pilot types may also be used for the pilot structure.

Table 33 - Pilot Types

Pilot Type	Description
Beacon Pilot	A pilot transmitted from all transmit antennas and used for timing and frequency acquisition.
MIMO Pilot	A pilot transmitted from all transmit antennas with different orthogonal codes and used for channel estimation.
Steered Reference or Steered Pilot	A pilot transmitted on specific eigenmodes of a MIMO channel for a specific user terminal and used for channel estimation and possibly rate control.
Carrier Pilot	A pilot used for phase tracking of a carrier signal.

Steered reference and steered pilot are synonymous terms.

[0376] In an embodiment, the pilot structure includes (1) for the downlink - a beacon pilot, a MIMO pilot, a steered reference, and a carrier pilot transmitted by the access point, and (2) for the uplink - a MIMO pilot, a steered reference, and a carrier pilot transmitted by the user terminals.

[0377] The downlink beacon pilot and MIMO pilot are sent on the BCH (as shown in FIG. 5A) in each TDD frame. The beacon pilot may be used by the user terminals for timing and frequency acquisition and Doppler estimation. The MIMO pilot may be used by the user terminals to (1) obtain an estimate of the downlink MIMO channel, (2) derive the steering vectors for uplink transmission (if the beam-steering or spatial multiplexing mode is supported), and (3) derive a matched filter for downlink transmission. The downlink steered reference may also be used by a specified user terminal for channel estimation.

[0378] An uplink steered reference is transmitted by each active user terminal that supports the beam-steering or spatial multiplexing mode and may be used by the access point to (1) derive the steering vectors for the downlink transmission and (2) derive a matched filter for the uplink transmission. In general, the steered reference is only sent for/by user terminals that support the beam-steering and/or spatial multiplexing modes. The reference sent works regardless of whether or not it is steered properly (e.g., due to a poor channel estimate). That is, the reference becomes

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orthogonal on a per transmit antenna basis since the steering matrix is diagonal.

[0379] If a user terminal is calibrated, then it can transmit a steered reference on the principal eigenmode on the RACH using the vector $\hat{\underline{\mathbf{K}}}_{ut}(k)\hat{\underline{\mathbf{v}}}_{ut,0}(k)$, for $k \in K$, where $\hat{\underline{\mathbf{v}}}_{ut,0}(k)$ is the column of $\hat{\underline{\mathbf{V}}}_{ut}(k)$ for the principal eigenmode. If the user terminal is not calibrated, then it can transmit a pilot on the RACH using a vector $\underline{\mathbf{v}}_{ut,p}(k)=[e^{j\theta 1(k)}\ e^{j\theta 2(k)}\ \ldots\ e^{j\theta Nut(k)}]^T$, for $k \in K$. The vector $\underline{\mathbf{v}}_{ut,p}(k)$ for each subband includes N_{ut} random steering coefficients whose phases $\theta_i(k)$, for $i \in \{1, 2, \ldots N_{ut}\}$, may be selected in accordance with a pseudo-random procedure. Since only the relative phases among the N_{ut} steering coefficients matter, the phase of the first steering coefficient may be set to zero (i.e., $\theta_1(k) = 0$). The phases of the other N_{ut}-1 steering coefficients may change for each access attempt, so that all 360° are covered by each steering coefficient in intervals of $360°/N_{\theta i}$, where $N_{\theta i}$ is a function of N_{ut}. The perturbation of the phases of the N_{ut} elements of the steering vector $\underline{\mathbf{v}}_{ut,p}(k)$ on every RACH attempt, when using the RACH in the beam-steering mode prior to calibration, is so that the user terminal does not use a bad steering vector for all access attempts. A MIMO pilot may be sent for/by user terminals that do not support beam-steering and/or spatial multiplexing modes.

[0380] The access point does not have knowledge of the channel for any user terminal until the user terminal communicates directly with the access point. When a user terminal desires to transmit data, it first estimates the channel based on the MIMO pilot transmitted by the access point. The user terminal then sends steered reference in the preamble of the RACH when it attempts to access the system. The access point uses the reference on the RACH preamble for signal detection and channel estimation.

[0381] Once the user terminal has been granted access to the system and assigned FCH/RCH resources by the access point, the user terminal sends a reference (e.g., a MIMO pilot) at the beginning of each RCH PDU it transmits. If the user terminal is using the diversity mode, then the reference is sent on the RCH without steering. If the user terminal is using the beam-steering or spatial multiplexing mode, then a steered reference is sent on the RCH to allow the access point to determine the eigenvector for the principal eigenmode (for the beam-steering mode) or the set of four eigenvectors (for the spatial multiplexing mode) for each of the 48 data subbands. The steered reference allows the access point to improve its estimate of the channel and to track the channel.

1. Beacon Pilot - Downlink

[0382] The downlink beacon pilot is included in the first portion of the BCH (as shown in FIG. 5A) and transmitted in each TDD frame. The beacon pilot includes a specific OFDM symbol (denoted as "B") that is transmitted from each of the four antennas at the access point. The same B OFDM symbol is transmitted twice in the 2-symbol duration for the beacon pilot.

[0383] In a specific embodiment, the B OFDM symbol comprises a set of 12 BPSK modulation symbols, $b(k)$, for 12 specific subbands, which is shown in Table 34.

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Table 34 - Pilot Symbols

Sub-band Index	Beacon Pilot $b(k)$	MIMO Pilot $p(k)$	Sub-band Index	Beacon Pilot $b(k)$	MIMO Pilot $p(k)$	Sub-band Index	Beacon Pilot $b(k)$	MIMO Pilot $p(k)$	Sub-band Index	Beacon Pilot $b(k)$	MIMO Pilot $p(k)$
M	0	0	-13	0	1-j	1	0	1-j	15	0	1+j
-26	0	-1-j	-12	-1-j	1-j	2	0	-1-j	16	1+j	-1+j
-25	0	-1+j	-11	0	-1-j	3	0	-1-j	17	0	-1+j
-24	1+j	-1+j	-10	0	-1-j	4	-1-j	-1-j	18	0	1-j
-23	0	-1+j	-9	0	1-j	5	0	-1+j	19	0	1+j
-22	0	1-j	-8	-1-j	-1-j	6	0	1+j	20	1+j	-1+j
-21	0	1-j	-7	0	1+j	7	0	-1-j	21	0	1+j
-20	-1-j	1+j	-6	0	-1+j	8	-1-j	-1+j	22	0	-1+j
-19	0	-1-j	-5	0	-1-j	9	0	-1-j	23	0	1+j
-18	0	-1+j	-4	1+j	-1+j	10	0	-1-j	24	1+j	-1+j
-17	0	1+j	-3	0	-1+j	11	0	1+j	25	0	1-j
-16	1+j	-1+j	-2	0	1-j	12	1+j	1-j	26	0	-1-j
-15	0	1-j	-1	0	-1+j	13	0	-1+j	N	0	0
-14	0	1+j	0	0	0	14	0	-1-j			

[0384] For the beacon pilot embodiment shown in Table 34, the B OFDM symbol comprises (1) BPSK modulation symbol $(1+j)$ for subbands -24, -16, -4, 12, 16, 20, and 24, (2) BPSK modulation symbol $-(1+j)$ for subbands -20, -12, -8, 4, and 8, and (3) signal values of zero for the remaining 52 subbands. The B OFDM symbol is specifically designed to facilitate timing and frequency acquisition by the user terminals. However, other OFDM symbols may also be used for the beacon pilot, and this is within the scope of the invention.

2. MIMO Pilot - Downlink

[0385] The downlink MIMO pilot is included in the second portion of the BCH (as shown in FIG. 5A) and also transmitted in each TDD frame. The MIMO pilot includes a specific OFDM symbol (denoted as "P") that is transmitted from each of the four antennas at the access point. The same P OFDM symbol is transmitted eight times in the 8-symbol duration for the MIMO pilot. However, the eight P OFDM symbols for each antenna are "covered" with a different 4-chip Walsh sequence assigned to that antenna. Covering is a process whereby a given pilot or data symbol (or a set of L pilot/data symbols with the same value) to be transmitted is multiplied by all L chips of an L-chip orthogonal sequence to obtain L covered symbols, which are then transmitted. Decovering is a complementary process whereby received symbols are multiplied by the L chips of the same L-chip orthogonal sequence to obtain L decovered symbols, which are then accumulated to obtain an estimate of the transmitted pilot/data symbol. The covering achieves orthogonality among the N_T pilot transmissions from the N_T transmit antennas and allows the user terminals to distinguish the individual transmit antennas. Covering may be achieved with Walsh sequences or other orthogonal sequences.

[0386] In a specific embodiment, the P OFDM symbol comprises a set of 52 QPSK modulation symbols, $p(k)$, for the 48 data subbands and 4 pilot subbands, which is shown in Table 34. Signal values of zero are transmitted on the remaining 12 subbands. The P OFDM symbol comprises a unique "word" of 52 QPSK modulation symbols that is designed to facilitate channel estimation by the user terminals. This unique word is also selected to minimize the peak-to-average variation in the transmitted MIMO pilot. This may then reduce the amount of distortion and non-linearity generated by the receiver circuitry at the user terminals, which can result in improved accuracy for the channel estimation. However, other OFDM symbols may also be used for the MIMO pilot, and this is within the scope of the invention.

[0387] In an embodiment, the four antennas at the access point are assigned 4-chip Walsh sequences of $W_1 = 1111$, $W_2 = 1010$, $W_3 = 1100$, and $W_4 = 1001$ for the MIMO pilot. For a given Walsh sequence, a value of "1" indicates that a P OFDM symbol is transmitted and a value of "0" indicates that a -P OFDM symbol is transmitted (i.e., each of the 52 modulation symbols in P is inverted).

[0388] Table 35 lists the OFDM symbols to be transmitted from each of the four antennas at the access point for the beacon pilot and MIMO pilot. The B and P OFDM symbols are as described above.

Table 35 - Beacon and MIMO Pilots

Pilot	OFDM Symbol	Antenna 1	Antenna 2	Antenna 3	Antenna 4
Beacon Pilot	1	B	B	B	B
	2	B	B	B	B
MIMO Pilot	3	+P	+P	+P	+P
	4	+P	-P	+P	-P
	5	+P	+P	-P	-P
	6	+P	-P	-P	+P
	7	+P	+P	+P	+P
	8	+P	-P	+P	-P
	9	+P	+P	-P	-P
	10	+P	-P	-P	+P

[0389] The MIMO pilot may be used by the user terminal to estimate the channel response of the downlink. In particular, to recover the pilot sent from access point antenna i and received by user terminal antenna j, the pilot received by terminal antenna j is first multiplied with the Walsh sequence assigned to access point antenna i. The eight decovered OFDM symbols for all eight symbol periods for the MIMO pilot are then accumulated, where the accumulation is performed individually for each of the 52 subbands' used to carry the MIMO pilot. The results of the accumulation is $\hat{h}_{cdn\ i,j}(k)$, for $k = \pm\{1, \ldots, 26\}$, which is an estimate of the calibrated downlink channel response from access point antenna i to user

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terminal antenna j for the 52 data and pilot subbands.

[0390] The same pilot processing may be performed by the access point to recover the pilot from each access point antenna at each user terminal antenna. The pilot transmitted from each access point antenna may be recovered by decovering with the Walsh sequence assigned to that antenna. The pilot processing provides $N_{ap} \cdot N_{ut}$ values for each of the 52 subbands, where N_{ap} denotes the number of antennas at the access point and N_{ut} denotes the number of antennas at the user terminal. The $N_{ap} \cdot N_{ut}$ values for each subband are the elements of the calibrated downlink channel response estimate $\hat{\underline{H}}_{cdn}(k)$ for that subband.

[0391] The MIMO pilot may also be transmitted on the uplink by the user terminal for calibration and in the diversity mode. The same processing described above for the user terminal to recover the MIMO pilot sent by the access point may also be performed by the access point to recover the MIMO pilot sent by the user terminal.

3. Steered Reference

[0392] A steered reference may be transmitted in the preamble portion of an RACH PDU (as shown in FIG. 5C) or an RCH PDU (as shown in FIGS. 5E and 5G) by each active user terminal. A steered reference may also be transmitted in the preamble portion of an FCH PDU (as shown in FIGS. 5E and 5F) by the access point to an active user terminal.

A. Steered Reference for Spatial Multiplexing

[0393] The steered reference comprises a specific OFDM symbol (e.g., the same P OFDM symbol used for the MIMO pilot) that is transmitted from all of the transmit antennas at the user terminal (for the uplink) or the access point (for the downlink). However, the P OFDM symbol for each symbol period is spatially processed (i.e., beam-formed) with a steering vector for one eigenmode.

[0394] The first symbol of steered reference transmitted by the user terminal in the preamble of the RACH may be expressed as:

$$\underline{x}(k) = \hat{\underline{K}}_{ut}(k) \cdot \hat{\underline{v}}_{ut,1}(k) \cdot p(k) \quad , \text{for } k \in K', \qquad \text{Eq (64)}$$

where $\underline{x}(k)$ is the transmit vector for subband k;
$\hat{\underline{K}}_{ut}(k)$ is the correction matrix for subband k for the user terminal;
$\hat{\underline{v}}_{ut,1}(k)$ is the steering vector for subband k of the principal wideband eigenmode;
$p(k)$ is the pilot symbol for subband k; and
$K' = \{-32, \ldots, 31\}$ is the set of indices for all 64 subbands.

The vector $\underline{x}(k)$ includes four transmit symbols for each value of k, which are to be transmitted from the four antennas at the user terminal. The steering vector $\hat{\underline{v}}_{ut,1}(k)$ is the first column of the matrix $\hat{\underline{V}}_{ut}(k)$ of right eigenvectors of the calibrated uplink channel response estimate $\hat{\underline{H}}_{cup}(k)$, where $\hat{\underline{V}}_{ut}(k) = [\hat{\underline{v}}_{ut,1}(k)\ \hat{\underline{v}}_{ut,2}(k)\ \hat{\underline{v}}_{ut,3}(k)\ \hat{\underline{v}}_{ut,4}(k)]$ and $\hat{\underline{v}}_{ut,i}(k)$ is the i-th column of $\hat{\underline{V}}_{ut}(k)$. The above assumes that the singular values in $\underline{\Sigma}(k)$ and the columns of $\hat{\underline{V}}_{ut}(k)$ are ordered as described above.

[0395] The second symbol of steered reference transmitted by the user terminal in the preamble of the RACH includes the data rate indicator (DRI) for the RACH PDU. The DRI indicates the rate used for the RACH message sent in the RACH PDU. The DRI is embedded in the second steered reference symbol by mapping the DRI to a specific QPSK symbol s_{dri}, as shown in Table 15. The s_{dri} symbol is then multiplied with the pilot symbol $p(k)$ before performing the spatial processing. The second symbol of steered reference for the RACH may be expressed as:

$$\underline{x}(k) = \hat{\underline{K}}_{ut}(k) \cdot \hat{\underline{v}}_{ut,1}(k) \cdot s_{dri} \cdot p(k) \quad , \text{for } k \in K'. \qquad \text{Eq (65)}$$

As shown in equations (64) and (65), only eigenvector $\hat{\underline{v}}_{ut,1}(k)$ for the principal eigenmode is used for the steered reference for the RACH.

[0396] A symbol of steered reference transmitted by the user terminal in the preamble of the RCH may be expressed as:

$$\underline{x}_{up,str,m}(k) = \hat{\underline{K}}_{ut}(k) \cdot \hat{\underline{v}}_{ut,m}(k) \cdot p(k) \quad , \text{for } k \in K', \qquad \text{Eq (66)}$$

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where $\underline{x}_{up,sr,m}(k)$ is the transmit vector for subband k of wideband eigenmode m; and
$\hat{\underline{v}}_{ut,m}(k)$ is the steering vector for subband k of wideband eigenmode m (i.e., the m-th column of $\hat{\underline{V}}_{ut}(k)$).

[0397] A symbol of steered reference transmitted by the access point in the preamble of the FCH may be expressed as:

$$\underline{x}_{dn,sr,m}(k) = \hat{\underline{K}}_{ap}(k) \cdot \hat{\underline{u}}^{*}_{ap,m}(k) p(k) \quad , \text{for } k \in K', \qquad \text{Eq (67)}$$

where $\underline{x}_{dn,sr,m}(k)$ is the transmit vector for subband k of wideband eigenmode m;
$\hat{\underline{K}}_{ap}(k)$ is the correction matrix for subband k for the access point; and
$\hat{\underline{u}}^{*}_{ap,m}(k)$ is the steering vector for subband k of wideband eigenmode m.
The steering vector $\hat{\underline{u}}_{ap,m}(k)$ is the m-th column of the matrix $\hat{\underline{U}}_{ap}(k)$ of right eigenvectors of the calibrated downlink channel response estimate $\hat{\underline{H}}_{cdn}(k)$, where $\hat{\underline{U}}_{ap}(k) = [\hat{\underline{u}}_{ap,1}(k)\ \hat{\underline{u}}_{ap,2}(k)\ \hat{\underline{u}}_{ap,3}(k)\ \hat{\underline{u}}_{ap,4}(k)]$.

[0398] The steered reference may be transmitted in various manners. In one embodiment, one or more eigenvectors are used for the steered reference for each TDD frame and are dependent on the duration of the steered reference, which is indicated by the FCH/RCH Preamble Type fields in the FCCH information element. Table 36 lists the eigenmodes used for the preamble for the FCH and RCH for various preamble sizes, for an exemplary design.

Table 36

Type	Preamble Size	Eigenmodes Used
0	0 OFDM symbol	no preamble
1	1 OFDM symbol	eigenmode m, where m = frame counter mod 4
2	4 OFDM symbols	cycle through all 4 eigenmodes in the preamble
3	8 OFDM symbols	cycle through all 4 eigenmodes twice in the preamble

[0399] As shown in Table 36, the steered reference is transmitted for all four eigenmodes within a single TDD frame when the preamble size is four or eight OFDM symbols. The steered reference transmitted by the user terminal for the n-th OFDM symbol in the preamble for the RCH may be expressed as:

$$\underline{x}_{up,sr,n}(k) = \hat{\underline{K}}_{ut}(k) \cdot \hat{\underline{v}}_{ut,n \bmod 4}(k) \cdot p(k) \quad , \text{for } k \in K' \text{ and } n = \{1, \ldots, L\}, \quad \text{Eq (68)}$$

where L is the preamble size, i.e., L = 4 for Type 2 and L = 8 for Type 3.

[0400] Similarly, the steered reference transmitted by the access point for the n-th OFDM symbol in the preamble for the FCH may be expressed as:

$$\underline{x}_{dn,sr,n}(k) = \hat{\underline{K}}_{ap}(k) \cdot \hat{\underline{u}}^{*}_{ap,n \bmod 4}(k) p(k) \quad , \text{for } k \in K' \text{ and } n = \{1, \ldots, L\}. \quad \text{Eq (69)}$$

As shown in equations (68) and (69), the four eigenmodes are cycled through in each 4-symbol period by the (n mod 4) operation for the steering vector. This scheme may be used if the channel changes more rapidly and/or during the early part of a connection when a good channel estimate needs to be obtained quickly for proper system operation.

[0401] In another embodiment, the steered reference is transmitted for one wideband eigenmode for each TDD frame. The steered reference for four wideband eigenmodes may be cycled through in four TDD frames. For example, the steering vectors $\hat{\underline{v}}_{ut,1}(k)$, $\hat{\underline{v}}_{ut,2}(k)$, $\hat{\underline{v}}_{ut,3}(k)$, and $\hat{\underline{v}}_{ut,4}(k)$ may be used for the first, second, third, and fourth TDD frames, respectively, by the user terminal. The particular steering vector to use may be specified by the 2 LSBs of the Frame Counter value in the BCH message. This scheme allows a shorter preamble portion to be used in the PDU but may require a longer time period to obtain a good estimate of the channel.

[0402] For both embodiments described above, the steered reference may be transmitted on all four eigenmodes that may be used for data transmission, even though fewer than four eigenmodes are currently used (e.g., because the unused eigenmodes are poor and discarded by the water-filling). The transmission of the steered reference on a currently unused eigenmode allows the receiver to determine when the eigenmode improves enough to be selected for use.

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B. Steered Reference for Beam-Steering

[0403] For the beam-steering mode, the spatial processing on the transmit side is performed using a set of normalized eigenvectors for the principal wideband eigenmode. The overall transfer function with a normalized eigenvector is different from the overall transfer function with an unnormalized eigenvector (i.e., $\underline{\mathbf{H}}_{cup}(k)\underline{\hat{\mathbf{v}}}_{ut,1}(k) \neq \underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)$). A steered reference generated using the set of normalized eigenvectors for all subbands may then be sent by the transmitter and used by the receiver to derive the matched filter vectors for these subbands for the beam-steering mode.

[0404] For the uplink, the steered reference for the beam-steering mode may be expressed as:

$$\underline{\tilde{\mathbf{x}}}_{up,sr}(k) = \underline{\hat{\mathbf{K}}}_{ut}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)p(k) \quad \text{, for } k \in K . \qquad \text{Eq (70)}$$

At the access point, the receive uplink steered reference for the beam-steering mode may be expressed as:

$$\begin{aligned} \underline{\tilde{\mathbf{r}}}_{up,sr}(k) &= \underline{\mathbf{H}}_{up}(k)\underline{\mathbf{x}}_{up,sr}(k) + \underline{\mathbf{n}}_{up}(k) \qquad \text{, for } k \in K . \qquad \text{Eq (71)} \\ &= \underline{\mathbf{H}}_{up}(k)\underline{\hat{\mathbf{K}}}_{ut}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)p(k) + \underline{\mathbf{n}}_{up}(k) \\ &= \underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)p(k) + \underline{\mathbf{n}}_{up}(k) \end{aligned}$$

[0405] To obtain the matched filter row vector $\underline{\tilde{\mathbf{m}}}_{ap}(k)$ for the uplink transmission with beam-steering, the received vector $\underline{\tilde{\mathbf{r}}}_{up,sr}(k)$ for the steered reference is first multiplied with $p^*(k)$. The result is then integrated over multiple received steered reference symbols to form an estimate of $\underline{\mathbf{H}}_{cup}(k)\underline{\tilde{\mathbf{v}}}_{ut}(k)$. The vector $\underline{\tilde{\mathbf{m}}}_{ap}(k)$ is then the conjugate transpose of this estimate.

[0406] While operating in the beam-steering mode, the user terminal may transmit multiple symbols of steered reference, for example, one or more symbols using the normalized eigenvector $\underline{\tilde{\mathbf{v}}}_{ut}(k)$, one or more symbols using the eigenvector $\underline{\hat{\mathbf{v}}}_{ut,1}(k)$ for the principal wideband eigenmode, and possibly one or more symbols using the eigenvectors for the other wideband eigenmodes. The steered reference symbols generated with $\underline{\tilde{\mathbf{v}}}_{ut}(k)$ may be used by the access point to derive the matched filter vector $\underline{\tilde{\mathbf{m}}}_{ap}(k)$. The steered reference symbols generated with $\underline{\hat{\mathbf{v}}}_{ut,1}(k)$ may be used to obtain $\underline{\hat{\mathbf{u}}}_{ap,1}(k)$, which may then be used to derive the normalized eigenvector $\underline{\tilde{\mathbf{u}}}_{ap}(k)$ that is used for beam-steering on the downlink. The steered reference symbols generated with the eigenvectors $\underline{\hat{\mathbf{v}}}_{ut,2}(k)$ through $\underline{\hat{\mathbf{v}}}_{ut,Ns}(k)$ for the other eigenmodes may be used by the access point to obtain $\underline{\tilde{\mathbf{u}}}_{ap,2}(k)$ through $\underline{\tilde{\mathbf{u}}}_{ap,NS}(k)$ and the singular values for these other eigenmodes. This information may then be used by the access point to determine whether to use the spatial multiplexing mode or the beam-steering mode for data transmission.

[0407] For the downlink, the user terminal may derive the matched filter vector $\underline{\tilde{\mathbf{m}}}_{ut}(k)$ for the beam-steering mode based on the calibrated downlink channel response estimate $\underline{\hat{\mathbf{H}}}_{cdn}(k)$. In particular, the user terminal has $\underline{\hat{\mathbf{u}}}_{ap,1}(k)$ from the singular value decomposition of $\underline{\hat{\mathbf{H}}}_{cdn}(k)$ and can derive the normalized eigenvector $\underline{\tilde{\mathbf{u}}}_{ap}(k)$. The user terminal can then multiply $\underline{\tilde{\mathbf{u}}}_{ap}(k)$ with $\underline{\hat{\mathbf{H}}}_{cdn}(k)$ to obtain $\underline{\hat{\mathbf{H}}}_{cdn}(k)\underline{\tilde{\mathbf{u}}}_{ap}(k)$, and may then derive $\underline{\tilde{\mathbf{m}}}_{ut}(k)$ based on $\underline{\hat{\mathbf{H}}}_{cdn}(k)\underline{\tilde{\mathbf{u}}}_{ap}(k)$. Alternatively, a steered reference may be sent by the access point using the normalized eigenvector $\underline{\tilde{\mathbf{u}}}_{ap}(k)$, and this steered reference may be processed by the user terminal in the manner described above to obtain $\underline{\tilde{\mathbf{m}}}_{ut}(k)$.

4. Carrier Pilot - Uplink

[0408] The OFDM subband structure described herein includes four pilot subbands with indices of -21, -7, 7, and 21. In an embodiment, a carrier pilot is transmitted on the four pilot subbands in all OFDM symbols that are not part of a preamble. The carrier pilot may be used by the receiver to track phase changes due to drifts in the oscillators at both the transmitter and receiver. This may provide improved data demodulation performance.

[0409] The carrier pilot comprises four pilot sequences, $P_{c1}(n)$, $P_{c2}(n)$, $P_{c3}(n)$, and $P_{c4}(n)$, which are transmitted on the four pilot subbands. The pilot sequences may be defined as:

$$P_{c1}(n) = P_{c2}(n) = P_{c3}(n) = -P_{c4}(n) \quad \text{, for } n = \{1, 2, \ldots 127\}, \qquad \text{Eq (72)}$$

where n is an index for OFDM symbol period.

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[0410] The pilot sequences may be defined based on various data sequences. In an embodiment, the pilot sequence $P_{c1}(n)$ is generated based on a polynomial $G(x)=x^7+x^4+x$, where the initial state is set to all ones and the output bits are mapped to signal values as follows: $1 \Rightarrow -1$ and $0 \Rightarrow 1$. The pilot sequence $P_{c1}(n)$, for $n = \{1, 2, \ldots 127\}$, may then be expressed as:

$$P_{c1}(n) = \{1,1,1,1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,-1,1,1,-1,1,1,-1,1,1,-1,1,1,1,1,1,-1,1,$$
$$1,1,-1,1,1,-1,-1,1,1,1,-1,1,-1,-1,-1,1,-1,1,-1,-1,1,-1,-1,1,1,1,1,1,-1,-1,1,1,$$
$$-1,-1,1,-1,1,-1,1,1,-1,-1,-1,1,1,-1,-1,-1,-1,1,-1,-1,1,-1,1,-1,1,1,1,1,-1,1,-1,1,-1,1,$$
$$-1,-1,-1,-1,-1,1,-1,1,1,-1,1,-1,1,1,1,-1,-1,1,-1,-1,-1,1,1,1,1,-1,-1,-1,-1,-1,-1,-1\}.$$

The values of "1" and "-1" in the pilot sequence $P_{c1}(n)$ may be mapped to pilot symbols using a particular modulation scheme. For example, using BPSK, a "1" may be mapped to $1 + j$ and a "-1" may be mapped to $-(1+j)$. If there are more than 127 OFDM symbols, then the pilot sequence may be repeated so that $P_{c1}(n) = P_{c1}(n \bmod 127)$ for $n > 127$.

[0411] In one embodiment, the four pilot sequences are reset for each transport channel. Thus, on the downlink, the pilot sequences are reset for the first OFDM symbol of the BCH message, reset again for the first OFDM symbol of the FCCH message, and reset for the first OFDM symbol sent on the FCH. In another embodiment, the pilot sequences are reset at the start of each TDD frame and repeat as often as needed. For this embodiment, the pilot sequences may be stalled during the preamble portions of the BCH and FCH.

[0412] In the diversity mode, the four pilot sequences are mapped to four subband/antenna pairing as shown in Table 29. In particular, $P_{c1}(n)$ is used for subband -21 of antenna 1, $P_{c2}(n)$ is used for subband -7 of antenna 2, $P_{c3}(n)$ is used for subband 7 of antenna 3, and $P_{c4}(n)$ is used for subband 21 of antenna 4. Each pilot sequence is then transmitted on the associated subband and antenna.

[0413] In the spatial multiplexing mode, the four pilot sequences are transmitted on the principal eigenmode of their respective subbands. The spatial processing for the carrier pilot symbols is similar to that performed for the modulation symbols, as described above. In the beam-steering mode, the four pilot sequences are transmitted on their respective subbands using beam-steering. The beam-steering for the carrier pilot symbols is also similar to that performed for the modulation symbols.

[0414] A specific pilot structure has been described above for the MIMO WLAN system. Other pilot structures may also be used for the system, and this is within the scope of the invention.

IX. System Operation

[0415] **FIG. 12A** shows a specific embodiment of a state diagram 1200 for the operation of a user terminal. This state diagram includes four states - an *Init* state 1210, a *Dormant* state 1220, an *Access* state 1230, and a *Connected* state 1240. Each of states 1210, 1220, 1230, and 1240 may be associated with a number of substates (not shown in FIG. 12A for simplicity).

[0416] In the *Init* state, the user terminal acquires the system frequency and timing and obtains system parameters sent on the BCH. In the *Init* state, the user terminal may perform the following functions:

- System determination - the user terminal determines which carrier frequency to acquire the system on.
- Frequency/timing acquisition - the user terminal acquires the beacon pilot and adjusts its frequency and timing accordingly.
- Parameter acquisition - the user terminal processes the BCH to obtain the system parameters associated with the access point from which the downlink signal is received.

Upon completing the required functions for the *Init* state, the user terminal transitions to the *Dormant* state.

[0417] In the *Dormant* state, the user terminal periodically monitors the BCH for updated system parameters, indications of pages and broadcast messages being sent on the downlink, and so on. No radio resources are allocated to the user terminal in this state. In the *Dormant* state, the user terminal may perform the following functions:

- If a registration is warranted, the user terminal enters the *Access* state with a registration request.
- If calibration of the transmitter/receiver is warranted, the user terminal enters the *Access* state with a calibration request.
- The user terminal monitors the BCH for indication of pages and broadcast messages sent on the FCH.

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- If the user terminal has data to send on the uplink, it enters the *Access* state with a resource request.
- The user terminal performs maintenance procedures such as updating the system parameters and tracking the channel.
- The user terminal may enter a slotted mode of operation for power savings, if this mode is supported by the user terminal.4

If the user terminal desires radio resources from the access point for any task, it transitions to the *Access* state. For example, the user terminal may transition to the *Access* state in response to a page or DST indicator being sent in the BCH message, for registration or request for calibration, or to request dedicated resources.

[0418] In the *Access* state, the user terminal is in the process of accessing the system. The user terminal may send short messages and/or requests for FCH/RCH resources using the RACH. The operation on the RACH is described in further detail below. If the user terminal is released by the access point, then it transitions back to the *Dormant* state. If the user terminal is assigned resources for the downlink and/or uplink, then it transitions to the *Connected* state.

[0419] In the *Connected* state, the user terminal is assigned the FCH/RCH resources, although not necessarily for every TDD frame. The user terminal may actively use the allocated resources or may be idle (while still maintaining the connection) in the *Connected* state. The user terminal remains in the *Connected* state until it is released by the access point or if it times out after no activity for a particular timeout period, in which case it transitions back to the *Dormant* state.

[0420] While in the *Dormant, Access,* or *Connected* state, the user terminal transitions back to the *Init* state if it is powered down or if the connection is dropped.

[0421] **FIG. 12B** shows a specific embodiment of a state diagram for *Connected* state 1240. In this embodiment, the *Connected* state includes three substates - a *Setup* substate 1260, an *Open* substate 1270, and an *Idle* substate 1280. The user terminal enters the *Setup* substate upon receiving an assignment on the FCCH.

[0422] In the *Setup* substate, the user terminal is in the process of setting up the connection and is not yet exchanging data. The connection setup may include channel estimation for the access point, rate determination, service negotiation, and so on. Upon entering the *Setup* substate, the user terminal sets a timer for a specified amount of time. If the timer expires before the user terminal leaves this substate, then it transitions back to the *Dormant* state. The user terminal transitions to the *Open* substate upon completion of the connection setup.

[0423] In the *Open* substate, the user terminal and access point exchange data on the downlink and/or uplink. While in the *Open* substate, the user terminal monitors the BCH for system parameters and indication of page/broadcast messages. If a BCH message cannot be decoded correctly within a specified number of TDD frames, then the user terminal transitions back to the *Init* state.

[0424] The user terminal also monitors the FCCH for channel assignment, rate control, RCH timing control, and power control information. The user terminal estimates the received SNR using the BCH beacon pilot and the FCH preamble and determines the maximum rate that can be sustained reliably on the FCH.

[0425] The FCH and RCH assignments for the user terminal for each TDD frame are given by the information elements in the FCCH PDU transmitted in the current (or possibly prior) TDD frame. The user terminal may not be assigned for data transmission on the FCH and/or RCH for any given TDD frame. For each TDD frame in which the user terminal is not scheduled for data transmission, it does not receive an FCH PDU on the downlink and does not transmit on the uplink.

[0426] For each TDD frame in which the user terminal is scheduled, the data transmissions on the downlink and/or uplink are performed using the rate, transmission mode, and RCH timing offset (for the uplink) indicated in the FCCH assignments (i.e., the FCCH information elements addressed to the user terminal). The user terminal receives, demodulates, and decodes FCH PDUs sent to it. The user terminal also transmits RCH PDUs, which include the preamble and FCH data rate indicator. The user terminal adjusts the rate used on the RCH according to the rate control information contained in the FCCH assignment. If power control is being applied for the uplink transmission, then the user terminal adjusts its transmit power based on the power control commands included in the FCCH assignment. The data exchange may be bursty, in which case the user terminal may enter into the *Idle* substate whenever no data is being exchanged. The user terminal enter the *Idle* substate when directed by the access point. If the access point does not assign the FCH or RCH to the user terminal within a specified number of TDD frames, then the user terminal transitions back to the *Dormant* state and retains its MAC ID.

[0427] In the *Idle* substate, both the uplink and downlink are idling. Data is not being sent in either direction. However, the links are maintained with the steered reference and control messages. In this substate, the access point periodically assigns Idle PDUs to the user terminal on the RCH and possibly the FCH (not necessarily simultaneously). The user terminal may be able to remain in the *Connected* state indefinitely, provided that the access point periodically assigns Idle PDUs on the FCH and RCH to maintain the link.

[0428] While in the *Idle* substate, the user terminal monitors the BCH. If a BCH message is not decoded correctly within a specified number of TDD frames, then the user terminal transitions back to the *Init* state. The user terminal also monitors the FCCH for channel assignment, rate control, RCH timing control, and power control information. The user terminal may also estimate the receive SNR and determine the maximum rate supported by the FCH. The user terminal

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transmits an Idle PDU on the RCH, when assigned, and sets the RCH Request bit in the Idle PDU if it has data to send. If the access point does not assign an FCH or RCH to the user terminal within a specified number of TDD frames, then the user terminal transitions back to the *Dormant* state and retains its MAC ID.

[0429] A time-out timer may be set to a particular value upon entering any of the three substates. This timer would then count down if there is no activity while in the substate. While in the *Setup, Active,* or *Idle* substate, the terminal would transition back to the *Dormant* state if the time-out timer expires and to the *Init* state if the connection is dropped. While in the *Active* or *Idle* substate, the terminal would also transition back to the *Dormant* state if the connection is released.

[0430] FIGS. 12A and 12B show a specific embodiment of a state diagram that may be used for the user terminal. Various other state diagrams with fewer, additional, and/or different states and substates may also be used for the system, and this is within the scope of the invention.

X. Random Access

[0431] In an embodiment, a random access scheme is employed to allow the user terminals to access the MIMO WLAN system. In an embodiment, the random access scheme is based on a slotted Aloha scheme whereby a user terminal transmits in a randomly selected RACH slot to attempt to gain access to the system. The user terminal may send multiple transmissions on the RACH until access is gained or the maximum number of access attempts has been reached. Various parameters for each RACH transmission may be changed to improve the likelihood of success, as described below.

[0432] **FIG. 13** illustrates a timeline for the RACH, which is partitioned into RACH slots. The number of RACH slots available for use in each TDD frame and the duration of the RACH slot are configurable parameters. A maximum of 32 RACH slots may be available for use in each TDD frame. The guard interval between the end of the last RACH slot and the start of the BCH PDU for the next TDD frame is also a configurable parameter. These three parameters for the RACH can change from frame to frame and are indicated by the RACH Length, RACH Slot Size, and RACH Guard Interval fields of the BCH message.

[0433] When a user terminal desires to access the system, it first processes the BCH to obtain pertinent system parameters. The user terminal then sends a RACH PDU on the RACH. This RACH PDU includes a RACH message that contains information needed by the access point to process the access request from the user terminal. For example, the RACH message includes the user terminal's assigned MAC ID that allows the access point to identify the user terminal. A registration MAC ID (i.e., a specific MAC ID value) may be reserved for unregistered user terminals. In this case, the user terminal's long ID may be included in the Payload field of the RACH message along with the registration MAC ID.

[0434] As described above, the RACH PDU may be transmitted at one of four data rates, which are listed in Table 15. The selected rate is embedded in the preamble of the RACH PDU (as shown in FIG. 5C). The RACH PDU also has a variable length of 1, 2, 4, or 8 OFDM symbols (as also listed in Table 15), which is indicated in the Message Duration field of the RACH message.

[0435] To transmit the RACH PDU, the user terminal first determines the number of RACH slots that may be used for transmission (i.e., the number of "usable" RACH slots). This determination is made based on (1) the number of RACH slots available in the current TDD frame, (2) the duration of each RACH slot, (3) the guard interval, and (4) the length of the RACH PDU to be transmitted. The RACH PDU cannot extend beyond the end of the RACH segment of the TDD frame. Thus, if the RACH PDU is longer than one RACH slot plus the guard interval, then this PDU may not be transmitted in one or more later available RACH slots. The number of RACH slots that may be used to transmit the RACH PDU may be fewer than the number of available RACH slots, based on the factors enumerated above. The RACH segment includes a guard interval, which is provided to prevent the uplink transmission from the user terminals from interfering with the next BCH segment, which is a possibility for user terminals that do not compensate for their round trip delay.

[0436] The user terminal then randomly selects one of the usable RACH slots to transmit the RACH PDU. The user terminal then transmits the RACH PDU starting in the selected RACH slot. If the user terminal knows the round trip delay to the access point, then it can account for this delay by adjusting its timing accordingly.

[0437] When the access point receives a RACH PDU, it checks the received RACH message using the CRC included in the message. The access point discards the RACH message if the CRC fails. If the CRC passes, the access point sets the RACH Acknowledgment bit on the BCH in the subsequent TDD frame and transmits an RACH acknowledgement on the FCCH within 2 TDD frames. There may be a delay between the: setting of the Acknowledgment bit on the BCH and the sending of the acknowledgment on the FCCH, which may be used to account for scheduling delay and so on. For example, if the access point receives the message on the RACH, it can set the Acknowledgment bit on the BCH and have a delay response on the FCCH. The Acknowledgment bit prevents user terminals from retrying and allows unsuccessful user terminals to retry quickly, except during busy RACH periods.

[0438] If the user terminal is performing a registration, then it uses the registration MAC ID (e.g., 0x0001). The access

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point responds by sending a MAC ID Assignment Message on the FCH. All other RACH transmission types include the user terminal's MAC ID assigned by the system. The access point explicitly acknowledges all correctly received RACH messages by sending acknowledgments on the FCCH using the MAC ID assigned to the user terminal.

[0439] After the user terminal sends the RACH PDU, it monitors the BCH and FCCH to determine whether or not its RACH PDU has been received and processed by the access point. The user terminal monitors the BCH to determine whether or not the RACH Acknowledgment Bit in the BCH message is set. If this bit is set, which indicates that an acknowledgment for this and/or some other user terminals is being sent on the FCCH, then the user terminal further processes the FCCH to obtain IE Type 3 information elements containing acknowledgements. Otherwise, if the RACH Acknowledgment Bit is not set, then the user terminal continues to monitor the BCH or resumes its access procedure on the RACH.

[0440] The FCCH IE Type 3 is used to carry quick acknowledgements for successful access attempts. Each acknowledgement information element contains the MAC ID associated with the user terminal for which the acknowledgment is sent. A quick acknowledgement is used to inform the user terminal that its access request has been received but is not associated with an assignment of FCH/RCH resources. Conversely, an assignment-based acknowledgement is associated with an FCH/RCH assignment. If the user terminal receives a quick acknowledgement on the FCCH, it transitions to the *Dormant* state. If the user terminal receives an assignment-based acknowledgement, it obtains scheduling information sent along with the acknowledgment and begins using the FCH/RCH as assigned in the current TDD frame.

[0441] The user terminal resumes the access procedure on the RACH if it does not receive an acknowledgement on the FCCH within a specified number of TDD frames after transmitting the RACH PDU. In this case, the user terminal can assume that the access point did not receive the RACH PDU correctly. A counter is maintained by the user terminal to count the number of access attempts. This counter may be initialized to zero for the first access attempt and is incremented by one for each subsequent access attempt. The user terminal would terminate the access procedure if the counter value reaches the maximum number of attempts.

[0442] For each subsequent access attempt, the user terminal first determines various parameters for this access attempt including (1) the amount of time to wait before transmitting the RACH PDU, (2) the RACH slot to use for the RACH PDU transmission, and (3) the rate for the RACH PDU. To determine the amount of time to wait, the user terminal first determines the maximum amount of time to wait for the next access attempt, which is referred to as the contention window (CW). In an embodiment, the contention window (which is given in units of TDD frames) exponentially increases for each access attempt (i.e., $CW = 2^{access\_attempt}$). The contention window may also be determined based on some other function (e.g., a linear function) of the number of access attempts. The amount of time to wait for the next access attempt is then randomly selected between zero and CW. The user terminal would wait this amount of time before transmitting the RACH PDU for the next access attempt.

[0443] For the next access attempt, the user terminal reduces the rate for the RACH PDU, if the lowest rate was not used for the last access attempt. The initial rate used for the first access attempt may be selected based on the received SNR of the pilot sent on the BCH. The failure to receive an acknowledgment may be caused by the access point's failure to correctly receive the RACH PDU. Thus, the rate for the RACH PDU in the next access attempt is reduced to improve the likelihood of correct reception by the access point.

[0444] After waiting the randomly selected wait time, the user terminal again randomly selects an RACH slot for transmission of the RACH PDU. The selection of the RACH slot for this access attempt may be performed in similar manner as that described above for the first access attempt, except that the RACH parameters (i.e., number of RACH slots, slot duration, and guard interval) for the current TDD frame, as conveyed in the BCH message, are used along with the current RACH PDU length. The RACH PDU is then transmitted in the randomly selected RACH slot.

[0445] The access procedure described above continues until either (1) the user terminal receives an acknowledgment from the access point or (2) the maximum number of permitted access attempts has been reached. For each access attempt, the amount of time to wait before transmitting the RACH PDU, the RACH slot to use for the RACH PDU transmission, and the rate for the RACH PDU may be selected as described above. If the acknowledgment is received, then the user terminal operates as indicated by the acknowledgment (i.e., it waits in the *Dormant* state if a quick acknowledgment is received or starts using the FCH/RCH if an assignment-based acknowledgment is received). If the maximum number of permitted access attempts has been reached, then the user terminal transitions back to the *Init* state.

XI. Rate, Power, and Timing Control

[0446] The access point schedules downlink and uplink transmissions on the FCH and RCH and further controls the rates for all active user terminals. Moreover, the access point adjusts the transmit power of certain active user terminals on the uplink. Various control loops may be maintained to adjust the rate, transmit power, and timing for each active user terminal.

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1. Fixed and Variable Rate Services

[0447] The access point can support both fixed and variable rate services on the FCH and RCH. Fixed-rate services may be used for voice, video, and so on. Variable rate services may be used for packet data (e.g., Web browsing).

[0448] For fixed rate services on the FCH/RCH, a fixed rate is used for the entire connection. Best effort delivery is used for the FCH and RCH (i.e., no retransmission). The access point schedules a constant number of FCH/RCH PDUs per specified time interval to satisfy the QoS requirements of the service. Depending on the delay requirements, the access point may not need to schedule an FCH/RCH PDU for every TDD frame. Power control is exercised on the RCH but not the FCH for fixed rate services.

[0449] For variable rate services on the FCH/RCH, the rate used for the FCH/RCH is allowed to change with channel conditions. For some isochronous services (e.g., video, audio), the QoS requirements may impose a minimum rate constraint. For these services, the scheduler at the access point adjusts the FCH/RCH allocation so that a constant rate is provided. For asynchronous data services (e.g., web browsing, file transfer, and so on), a best effort delivery is provided with the option of retransmissions. For these services, the rate is the maximum that can be reliably sustained by the channel conditions. The scheduling of the FCH/RCH PDUs for the user terminals is typically a function of their QoS requirements. Whenever there's no data to send on the downlink/uplink, an idle PDU is sent on the FCH/RCH to maintain the link. Closed loop power control is not exercised on the FCH or RCH for variable rate services.

2. Rate Control

[0450] Rate control may be used for variable rate services operating on the FCH and RCH to adapt the rate of the FCH/RCH to changing channel conditions. The rates to use for the FCH and RCH may be independently controlled. Moreover, in the spatial multiplexing mode, the rate for each wideband eigenmode of each dedicated transport channel may be independently controlled. The rate control is performed by the access point based on feedback provided by each active user terminal. The scheduler within the access point schedules data transmission and determines rate assignments for the active user terminals.

[0451] The maximum rate that can be supported on either link is a function of (1) the channel response matrix for all of the data subbands, (2) the noise level observed by the receiver, (3) the quality of the channel estimate, and possibly other factors. For a TDD system, the channel may be considered to be reciprocal for the downlink and uplink (after calibration has been performed to account for any differences at the access point and user terminal). However, this reciprocal channel does not imply that the noise floors are the same at the access point and user terminal. Thus, for a given user terminal, the rates on the FCH and RCH may be independently controlled.

[0452] Closed-loop rate control may be used for data transmission on one or more spatial channels. Closed-loop rate control may be achieved with one or multiple loops. An inner loop estimates the channel conditions and selects a suitable rate for each spatial channel used for data transmission. The channel estimation and rate selection may be performed as described above. An outer loop may be used to estimate the quality of the data transmission received on each spatial channel and to adjust the operation of the inner loop. The data transmission quality may be quantified by packet error rate (PER), decoder metrics, and so on, or a combination thereof. For example, the outer loop may adjust the SNR offset for each spatial channel to achieve the target PER for that spatial channel. The outer loop may also direct the inner loop to select a lower rate for a spatial channel if excessive packet errors are detected for the spatial channel.

Downlink Rate Control

[0453] Each active user terminal can estimate the downlink channel based on the MIMO pilot transmitted on the BCH in each TDD frame. The access point may also transmit a steered reference in an FCH PDU sent to a specific user terminal. Using the MIMO pilot on the BCH and/or the steered reference on the FCH, the user terminal can estimate the received SNR and determine the maximum rate that can be supported on the FCH. If the user terminal is operating in the spatial multiplexing mode, then the maximum rate may be determined for each wideband eigenmode. Each user terminal can send back to the access point the maximum rate supported by each wideband eigenmode (for the spatial multiplexing mode), the maximum rate supported by the principal wideband eigenmode (for the beam-steering mode), or the maximum rate supported by the MIMO channel (for the diversity mode) in the FCH Rate Indicator field of the RCH PDU. These rates may be mapped to received SNRs, which may then be used to perform the water-filling described above. Alternatively, the user terminal may send back sufficient information (e.g., the received SNRs) to allow the access point to determine the maximum rate supported by the downlink.

[0454] The determination of whether to use the diversity, beam-steering, or spatial multiplexing mode may be made based on the feedback from the user terminal. The number of wideband eigenmodes selected for use may increase as isolation between the steering vectors improves.

[0455] **FIG. 14A** illustrates a process for controlling the rate of a downlink transmission for a user terminal. A BCH

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PDU is transmitted in the first segment of each TDD frame and includes the beacon and MIMO pilots that can be used by the user terminals to estimate and track the channel. A steered reference may also be sent in the preamble of an FCH PDU sent to the user terminal. The user terminal estimates the channel based on the MIMO and/or steered reference and determines the maximum rate(s) that can be supported by the downlink. One rate is provided for each wideband eigenmode if the user terminal is operating in the spatial multiplexing mode. The user terminal then sends the rate indicator for the FCH in the FCH Rate Indicator field of the RCH PDU it sends to the access point.

[0456] The scheduler uses the maximum rates that the downlink can support for each active user terminal to schedule downlink data transmission in subsequent TDD frames. The rates and other channel assignment information for the user terminal are reflected in an information element sent on the FCCH. The rate assigned to one user terminal can impact the scheduling for other user terminals. The minimum delay between the rate determination by the user terminal and its use is approximately a single TDD frame.

[0457] Using the Gram-Schmidt ordered procedure, the access point can accurately determine the maximum rates supported on the FCH directly from the RCH preamble. This can then greatly simplify rate control.

Uplink Rate Control

[0458] Each user terminal transmits a steered reference on the RACH during system access and on the RCH upon being assigned FCH/RCH resources. The access point can estimate the received SNR for each of the wideband eigenmodes based on the steered reference on the RCH and determine the maximum rate supported by each wideband eigenmode. Initially, the access point may not have a good estimate of the channel to permit reliable operation at or near the maximum rate supported by each wideband eigenmode. To improve reliability, the initial rate used on the FCH/RCH may be much lower than the maximum supported rate. The access point can integrate the steered reference over a number of TDD frames to obtain improved estimate of the channel. As the estimate of the channel improves, the rate may be increased.

[0459] **FIG. 14B** illustrates a process for controlling the rate of an uplink transmission for a user terminal. When scheduled for uplink transmission, the user terminal transmits an RCH PDU that includes the reference, which is used by the access point to determine the maximum rate on the uplink. The scheduler then uses the maximum rates that the uplink can support for each active user terminal to schedule uplink data transmission in subsequent TDD frames. The rates and other channel assignment information for the user terminal are reflected in an information element sent on the FCCH. The minimum delay between the rate determination by the access point and its use is approximately a single TDD frame.

3. Power Control

[0460] Power control may be used for uplink transmissions on the RCH (instead of rate control) for fixed-rate services. For fixed-rate services, the rate is negotiated at call setup and remains fixed for the duration of the connection. Some fixed-rate services may be associated with limited mobility requirement. In an embodiment, power control is implemented for the uplink to guard against interference among the user terminals but is not used for the downlink.

[0461] A power control mechanism is used to control the uplink transmit power of each active user terminal such that the received SNR at the access point is maintained at a level that achieves the desired service quality. This level is often referred to as the target received SNR, the operating point, or the setpoint. For a mobile user terminal, the propagation loss will likely change as the user terminal moves about. The power control mechanism tracks changes in the channel so that the received SNR is maintained near the setpoint.

[0462] The power control mechanism may be implemented with two power control loops - an inner loop and an outer loop. The inner loop adjusts the transmit power of the user terminal such that the received SNR at the access point is maintained near the setpoint. The outer loop adjusts the setpoint to achieve a particular level of performance, which may be quantified by a particular frame error rate (FER) (e.g., 1% FER), packet error rate (PER), block error rate (BLER), message error rate (MER), or some other measure.

[0463] **FIG. 15** illustrates the operation of the inner power control for a user terminal. After the user terminal is assigned the FCH/RCH, the access point estimates the received SNR on the RCH and compares it to the setpoint. The initial power to be used by the user terminal may be determined at call setup and is typically near its maximum transmit power level. For each frame interval, if the received SNR exceeds the setpoint by a particular positive margin δ, then the access point can direct the user terminal to reduce its transmit power by a particular amount (e.g., 1 dB) in an FCCH information element sent to this user terminal. Conversely, if the received SNR is lower than the threshold minus the margin δ, then the access point can direct the user terminal to increase its transmit power by the particular amount. If the received SNR is within the acceptable limits of the setpoint, then the access point will not request a change in transmit power by the user terminal. The uplink transmit power is given as the initial transmit power level plus the sum of all power adjustments received from the access point.

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[0464] The initial setpoint used at the access point is set to achieve a particular level of performance. This setpoint is adjusted by the outer loop based on the FER or PER for the RCH. For example, if no frame/packet errors occur over a specified time period, then the setpoint may be reduced by a first amount (e.g., 0.1 dB). If the average FER is exceeded by the occurrence of one or more frame/packet errors, then the setpoint may be increased by a second amount (e.g., 1 dB). The setpoint, hysteresis margin, and outer loop operation are specific to the power control design used for the system.

4. Timing Control

[0465] Timing control may be advantageously used in a TDD-based frame structure where the downlink and uplink share the same frequency band in a time division duplexed manner. The user terminals may be located throughout in the system and may thus be associated with different propagation delays to the access point. In order to maximize efficiency on the uplink, the timing of the uplink transmission on the RCH and RACH from each user terminal can be adjusted to account for its propagation delay. This would then ensure that the uplink transmissions from different user terminals arrive within a particular time window at the access point and do not interfere with one another on the uplink, or with the downlink transmission.

[0466] **FIG. 16** illustrates a process for adjusting the uplink timing of a user terminal. Initially, the user terminal sends an RACH PDU on the uplink to gain access to the system. The access point derives an initial estimate of the round trip delay (RTD) associated with the user terminal. The round trip delay may be estimated based on (1) a sliding correlator used at the access point to determine the start of transmission, and (2) the slot ID included in the RACH PDU sent by the user terminal. The access point then computes an initial timing advance for the user terminal based on the initial RTD estimate. The initial timing advance is sent to the user terminal prior to its transmission on the RCH. The initial timing advance may be sent in a message on the FCH, a field of an FCCH information element, or by some other means.

[0467] The user terminal receives the initial timing advance from the access point and thereafter uses this timing advance on all subsequent uplink transmissions on both the RCH and RACH. If the user terminal is assigned FCH/RCH resources, then its timing advance can be adjusted by commands sent by the access point in the RCH Timing Adjustment field of an FCCH information element. The user terminal would thereafter adjust its uplink transmissions on the RCH based on the current timing advance, which is equal to the initial timing advance plus all timing adjustments sent by the access point to the user terminal.

[0468] Various parts of the MIMO WLAN system and various techniques described herein may be implemented by various means. For example, the processing at the access point and user terminal may be implemented in hardware, software, or a combination thereof. For a hardware implementation, the processing may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof.

[0469] For a software implementation, the processing may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit (e.g., memory 732 or 782 in FIG. 7) and executed by a processor (e.g., controller 730 or 780). The memory unit may be implemented within the processor or external to the processor, in which case it can be communicatively coupled to the processor via various means as is known in the art.

[0470] Headings are included herein for reference and to aid in locating certain sections. These headings are not intended to limit the scope of the concepts described therein under, and these concepts may have applicability in other sections throughout the entire specification.

[0471] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

Claims

1. A method of processing data for transmission in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

   coding a data frame in accordance with a coding scheme to obtain a coded data frame;
   partitioning the coded data frame into a plurality of coded data subframes, one coded data subframe for each

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of a plurality of spatial channels;
interleaving each coded data subframe in accordance with an interleaving scheme to obtain a corresponding interleaved data subframe, wherein a plurality of interleaved data subframes are obtained for the plurality of spatial channels; and
modulating each interleaved data subframe to obtain a corresponding stream of modulation symbols, wherein a plurality of modulation symbol streams are obtained for the plurality of spatial channels.

2. The method of claim 1, wherein the coded data frame is partitioned by completely filling one coded data subframe at a time.

3. The method of claim 1, wherein the coded data frame is partitioned by cycling through the plurality of coded data subframes for a plurality of iterations and partially filling each coded data subframe with a particular number of code bits from the coded data frame in each iteration.

4. The method of claim 1, wherein each of the plurality of spatial channels is associated with a respective rate, wherein the rate for each spatial channel indicates a particular modulation scheme and a particular code rate to use for the spatial channel, and wherein the particular modulation scheme is selected from among a plurality of modulation schemes supported by the system and the particular code rate is selected from among a plurality of code rates supported by the system.

5. The method of claim 4, wherein the plurality of code rates are obtained based on a single base code and a plurality of puncturing patterns.

6. The method of claim 1, further comprising:

puncturing each coded data subframe to obtain a code rate selected for the spatial channel for the coded data subframe.

7. The method of claim 1, wherein the MIMO system utilizes orthogonal frequency division multiplexing (OFDM).

8. The method of claim 7, wherein the coded data frame is partitioned by cycling through the plurality of coded data subframes for a plurality of iterations and partially filling each coded data subframe with code bits, from the coded data frame, for a group of M subbands in each iteration, where M is greater than one and less than a total number of subbands used for data transmission.

9. The method of claim 8, wherein the interleaving is performed for the code bits for each group of M subbands.

10. The method of claim 7, further comprising:

processing the plurality of modulation symbol streams to obtain a plurality of streams of OFDM symbols, wherein the OFDM symbols have a cyclic prefix length selected from among at least two cyclic prefix lengths supported by the system.

11. The method of claim 7, further comprising:

processing the plurality of modulation symbol streams to obtain a plurality of streams of OFDM symbols, wherein the OFDM symbols are of a size selected from among at least two OFDM symbol sizes supported by the system.

12. An apparatus in a wireless multiple-input multiple-output (MIMO) communication system, comprising:

means for coding a data frame in accordance with a coding scheme to obtain a coded data frame;
means for partitioning the coded data frame into a plurality of coded data subframes, one coded data subframe for each of a plurality of spatial channels;
means for interleaving each coded data subframe in accordance with an interleaving scheme to obtain a corresponding interleaved data subframe, wherein a plurality of interleaved data subframes are obtained for the plurality of spatial channels; and
means for modulating each interleaved data subframe to obtain a corresponding stream of modulation symbols, wherein a plurality of modulation symbol streams are obtained for the plurality of spatial channels.

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13. The apparatus of claim 12, wherein each of the plurality of spatial channels is associated with a respective rate, wherein the rate for each spatial channel indicates a particular modulation scheme and a particular code rate to use for the spatial channel, and wherein the particular modulation scheme is selected from among a plurality of modulation schemes supported by the system and the particular code rate is selected from among a plurality of code rates supported by the system.

14. The apparatus of claim 12, wherein the MIMO system utilizes orthogonal frequency division multiplexing (OFDM).

15. The apparatus of claim 14, wherein the coded data frame is partitioned by cycling through the plurality of coded data subframes for a plurality of iterations and partially filling each coded data subframe with code bits, from the coded data frame, for a group of M subbands in each iteration, where M is greater than one and less than a total number of subbands used for data transmission.

16. The apparatus of claim 14, further comprising:

means for processing the plurality of modulation symbol streams to obtain a plurality of streams of OFDM symbols, wherein the OFDM symbols have a cyclic prefix length selected from among at least two cyclic prefix lengths supported by the system.

17. The apparatus of claim 14, further comprising:

means for processing the plurality of modulation symbol streams to obtain a plurality of streams of OFDM symbols, wherein the OFDM symbols are of a size selected from among at least two OFDM symbol sizes supported by the system.

18. The apparatus of claims 16 or 17, wherein the means for processing the plurality of modulation symbol streams is a plurality of OFDM modulators.

19. The apparatus of any of claims 12 to 18 wherein:

the means for coding is an encoder;
the means for partitioning is a demultiplexer;
the means for interleaving is an interleaver; and
the means for modulating is a symbol mapping unit.

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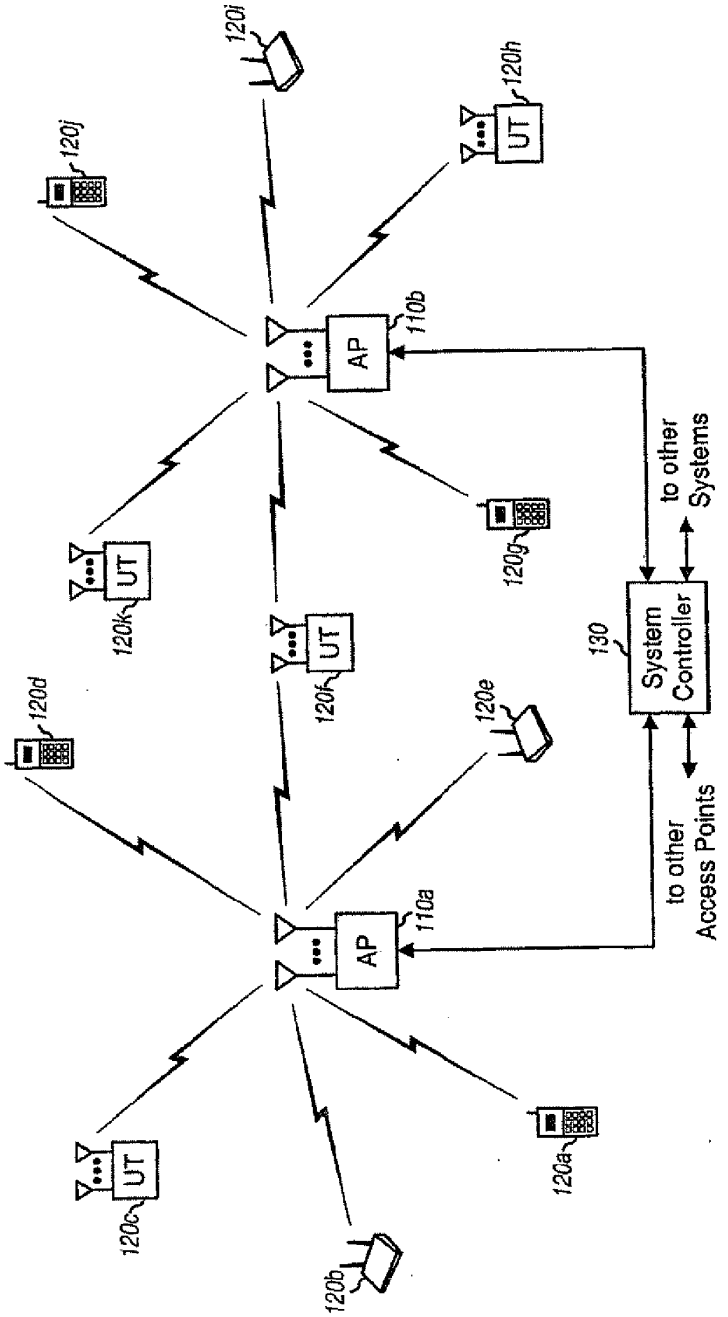

100
120i
120h
120j
UT
AP
110b
to other Systems
120g
120k
UT
120f
UT
120d
120e
130
System Controller
to other Access Points
AP
110a
120c
UT
120b
120a

FIG. 1

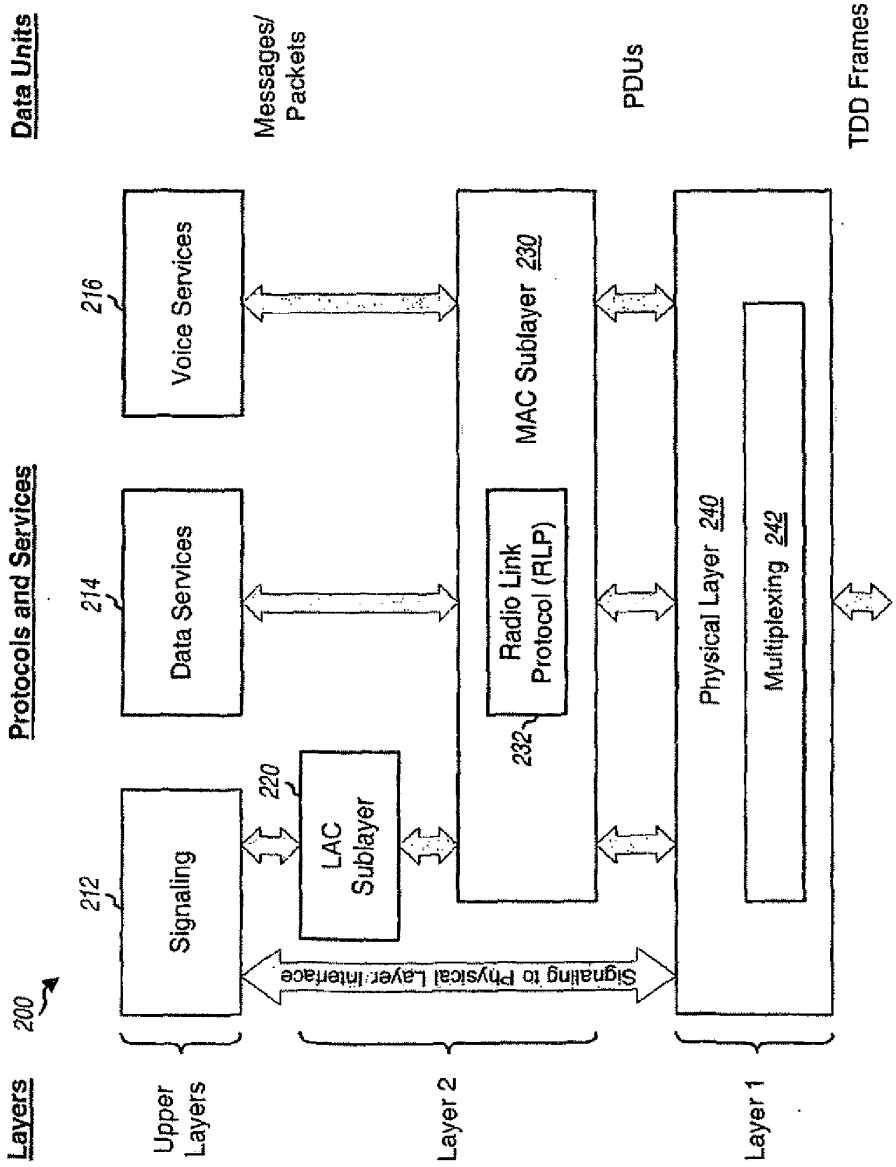

Layers
200
Protocols and Services
Data Units
Upper Layers
Layer 2
Layer 1
212
Signaling
220
LAC Sublayer
214
Data Services
216
Voice Services
232
Radio Link Protocol (RLP)
MAC Sublayer 230
Physical Layer 240
Multiplexing 242
Signaling to Physical Layer Interface
Messages/ Packets
PDUs
TDD Frames

FIG. 2

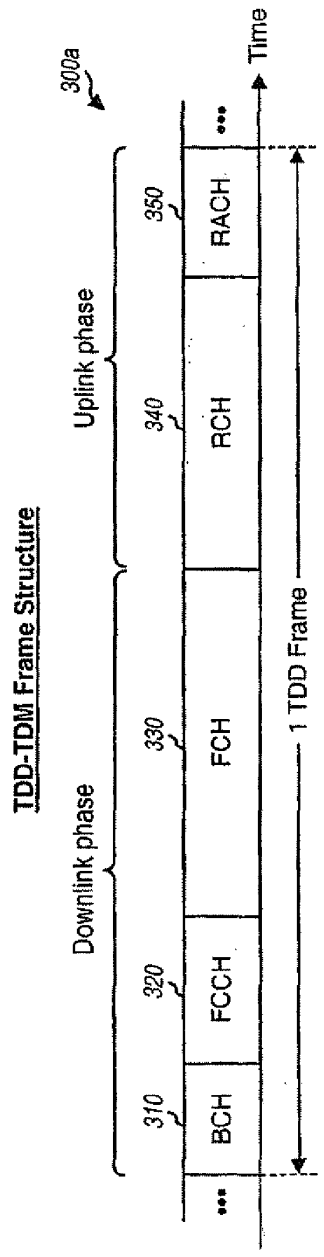

TDD-TDM Frame Structure
300a
Downlink phase
Uplink phase
310
BCH
320
FCCH
330
FCH
340
RCH
350
RACH
Time
1 TDD Frame

FIG. 3A

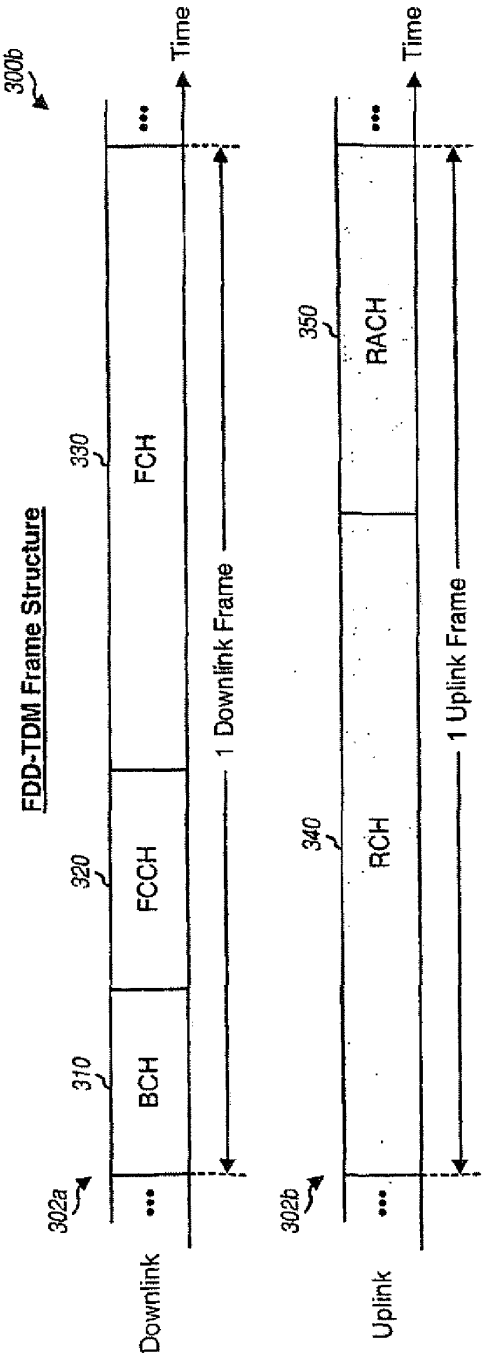

FDD-TDM Frame Structure
300b
302a
Downlink
310
BCH
320
FCCH
330
FCH
Time
1 Downlink Frame
302b
Uplink
340
RCH
350
RACH
Time
1 Uplink Frame

FIG. 3B

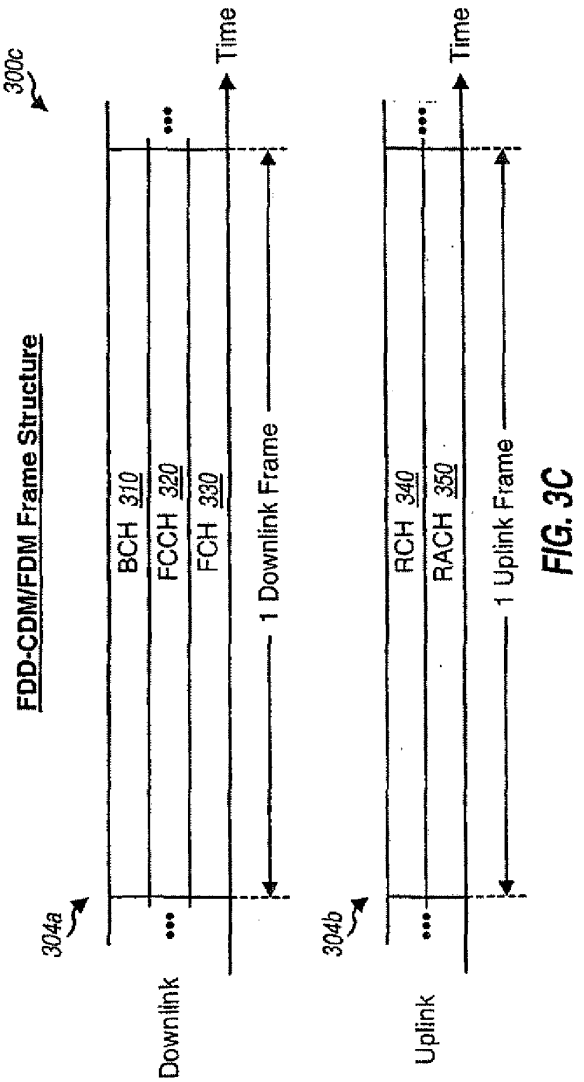

FDD-CDM/FDM Frame Structure
300c
Time
BCH 310
FCCH 320
FCH 330
1 Downlink Frame
304a
Downlink
RCH 340
RACH 350
1 Uplink Frame
304b
Uplink

FIG. 3C

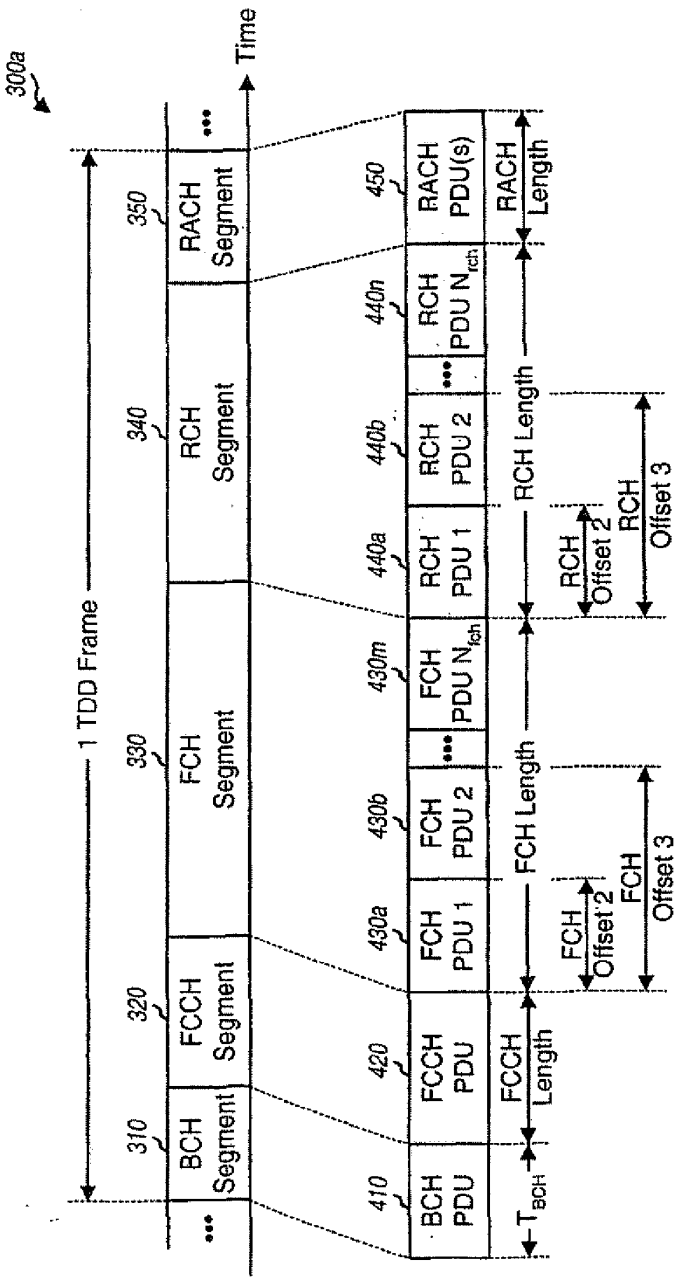

300a
Time
1 TDD Frame
BCH Segment
FCCH Segment
FCH Segment
RCH Segment
RACH Segment
310
320
330
340
350
BCH PDU
FCCH PDU
FCH PDU 1
FCH PDU 2
FCH PDU N_{fch}
RCH PDU 1
RCH PDU 2
RCH PDU N_{rch}
RACH PDU(s)
410
420
430a
430b
430m
440a
440b
440n
450
T_{BCH}
FCCH Length
FCH Length
RCH Length
RACH Length
FCH Offset 2
FCH Offset 3
RCH Offset 2
RCH Offset 3

FIG. 4

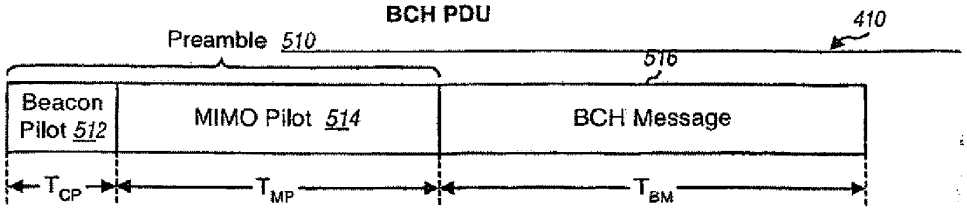


FIG. 5A

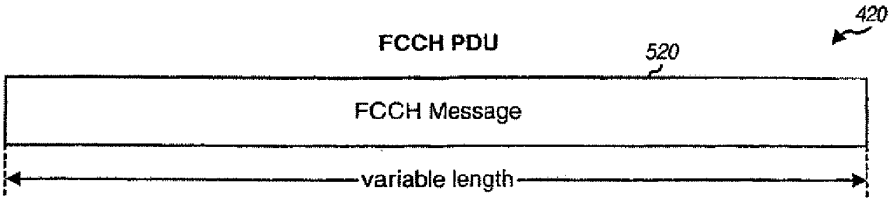


FIG. 5B

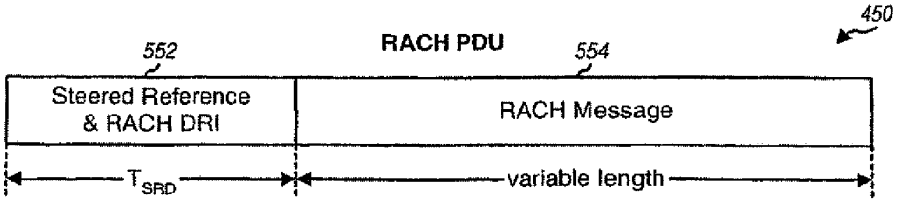


FIG. 5C

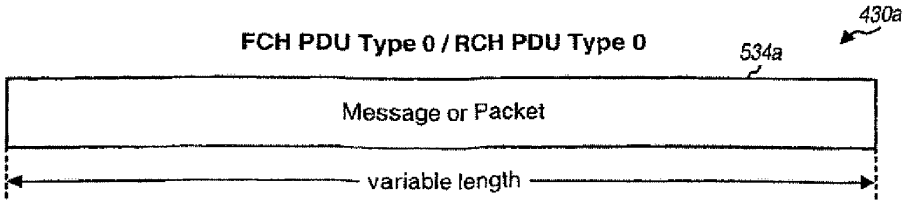


FIG. 5D

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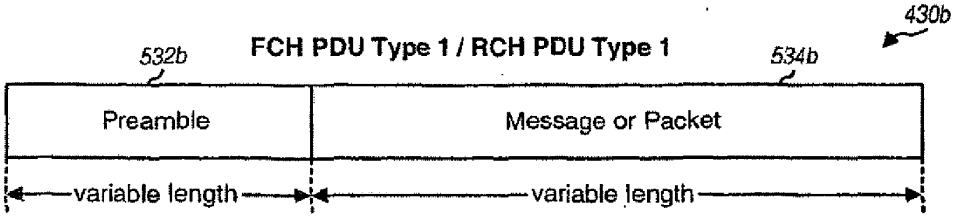


FIG. 5E

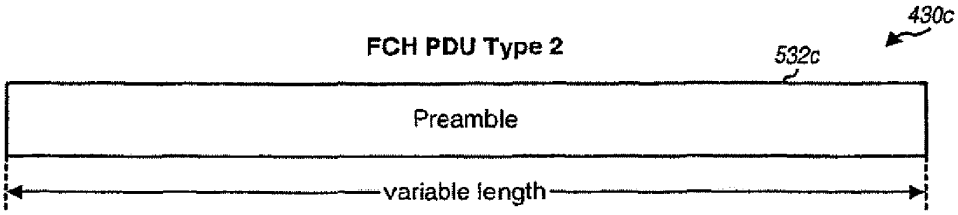


FIG. 5F

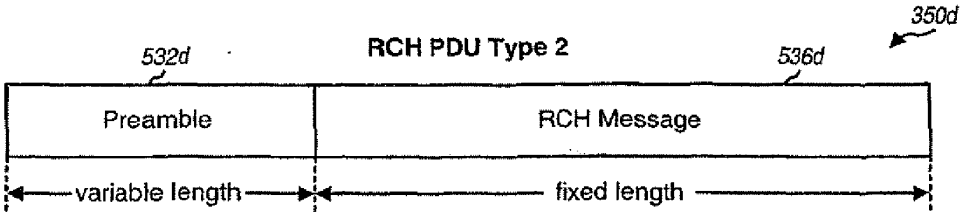


FIG. 5G

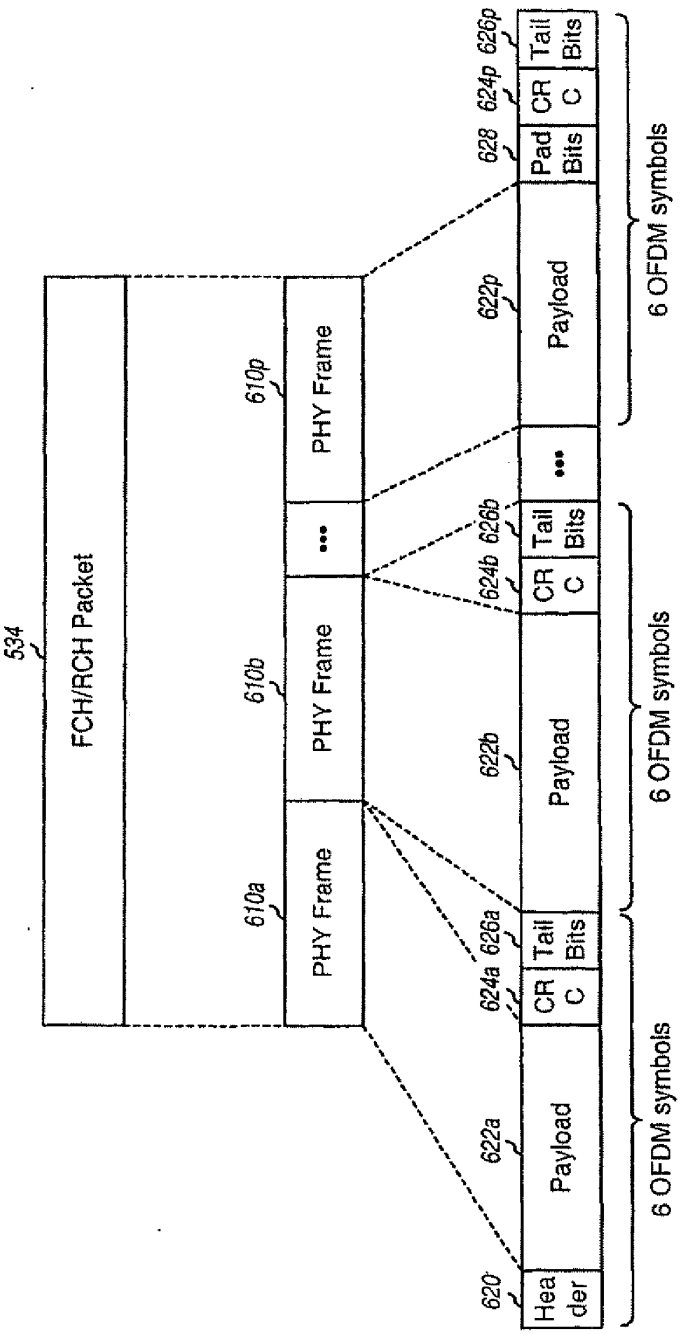

534
FCH/RCH Packet
610a
PHY Frame
610b
PHY Frame
610p
PHY Frame
620
Hea der
622a
Payload
624a
CR C
626a
Tail Bits
622b
Payload
624b
CR C
626b
Tail Bits
622p
Payload
628
Pad Bits
624p
CR C
626p
Tail Bits
6 OFDM symbols
6 OFDM symbols
6 OFDM symbols

FIG. 6

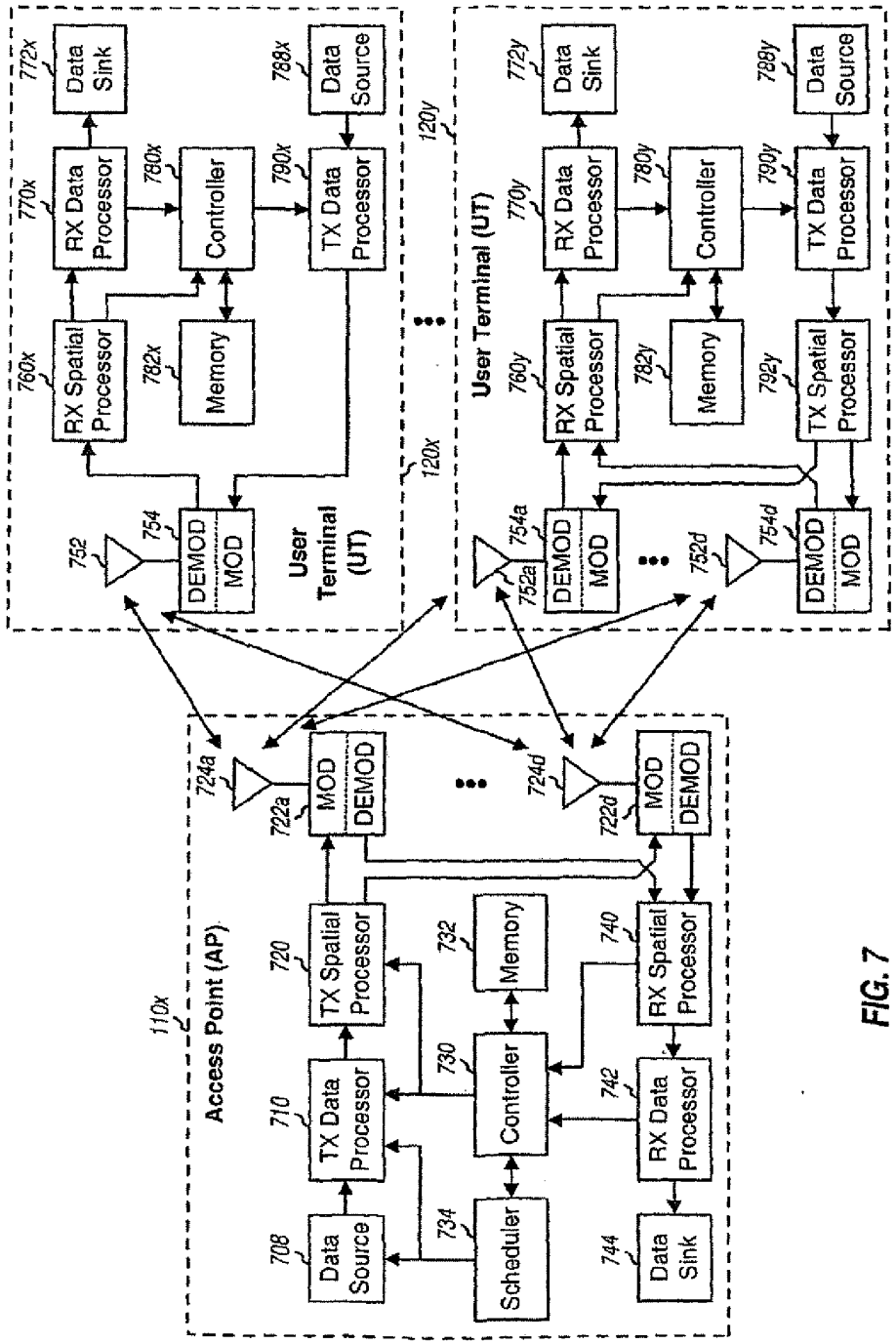

User Terminal (UT)
120x
User Terminal (UT)
120y
Data Sink
772x
RX Data Processor
770x
Controller
780x
TX Data Processor
790x
Data Source
788x
RX Spatial Processor
760x
Memory
782x
TX Spatial Processor
792x
DEMOD
MOD
754
752
Data Sink
772y
RX Data Processor
770y
Controller
780y
TX Data Processor
790y
Data Source
788y
RX Spatial Processor
760y
Memory
782y
TX Spatial Processor
792y
DEMOD
MOD
754a
752a
754d
752d
Access Point (AP)
110x
MOD
DEMOD
724a
722a
724d
722d
TX Spatial Processor
720
Memory
732
RX Spatial Processor
740
TX Data Processor
710
Controller
730
RX Data Processor
742
Data Source
708
Scheduler
734
Data Sink
744

FIG. 7

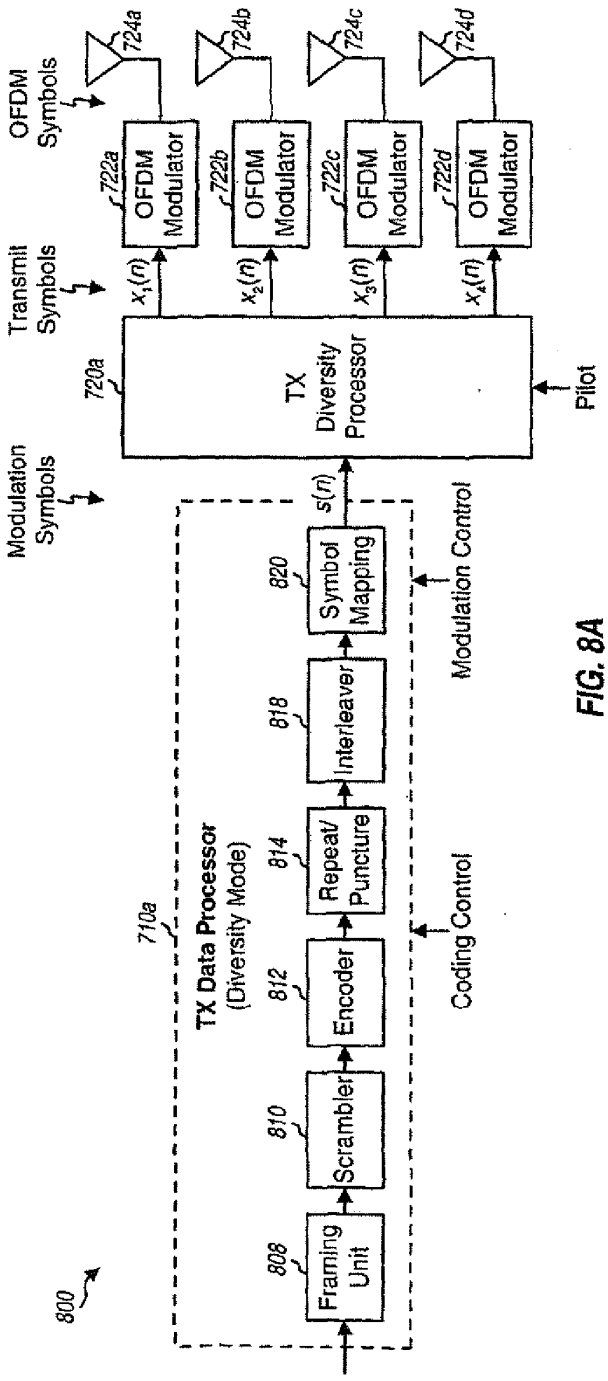


FIG. 8A

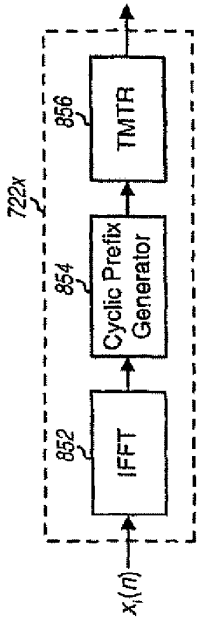


FIG. 8C

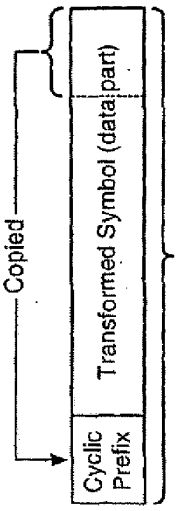


FIG. 8D

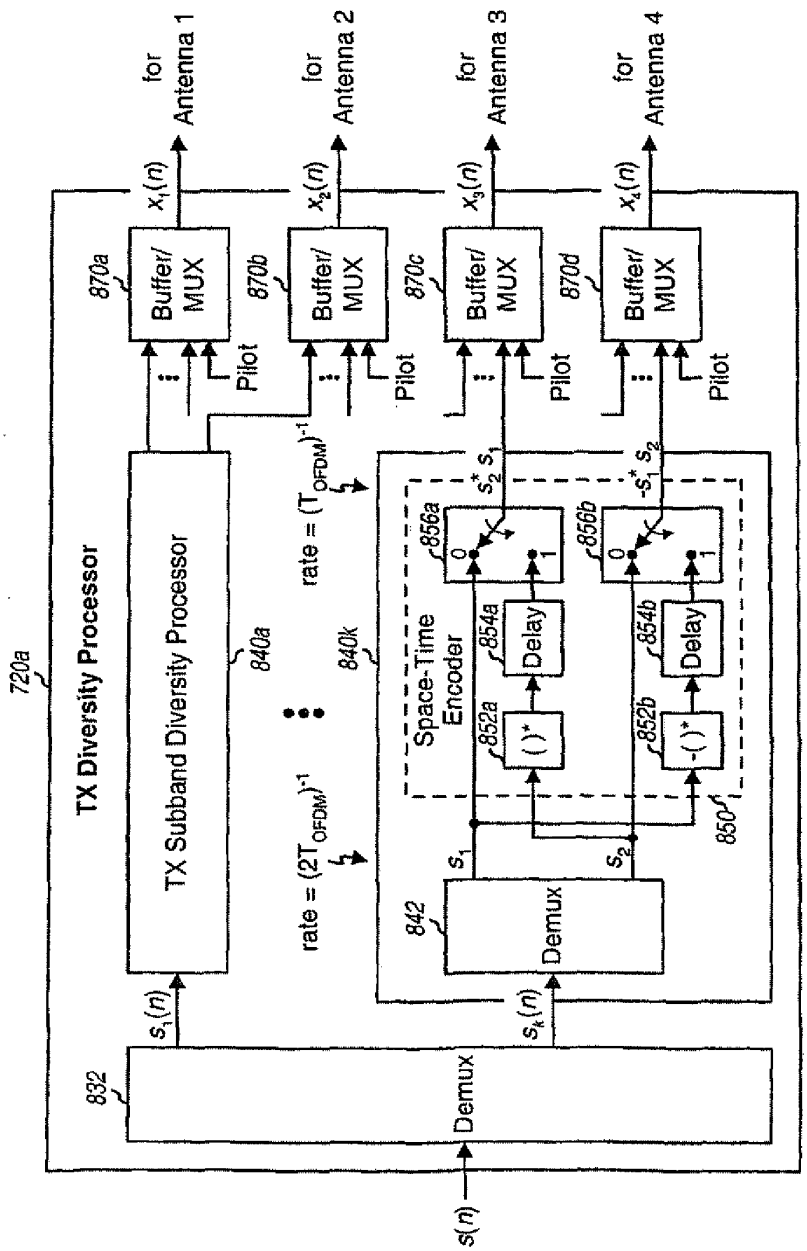

TX Diversity Processor
720a
TX Subband Diversity Processor
840a
840k
rate = $(T_{OFDM})^{-1}$
rate = $(2T_{OFDM})^{-1}$
Space-Time Encoder
Demux
842
Demux
832
Buffer/ MUX
870a
870b
870c
870d
Pilot
for Antenna 1
for Antenna 2
for Antenna 3
for Antenna 4
Delay
( )*
-( )*
856a
856b
852a
852b
854a
854b
850
$s(n)$
$s_1(n)$
$s_k(n)$
$x_1(n)$
$x_2(n)$
$x_3(n)$
$x_4(n)$
s_1
s_2
$s_2^* s_1$
$-s_1^* s_2$

FIG. 8B

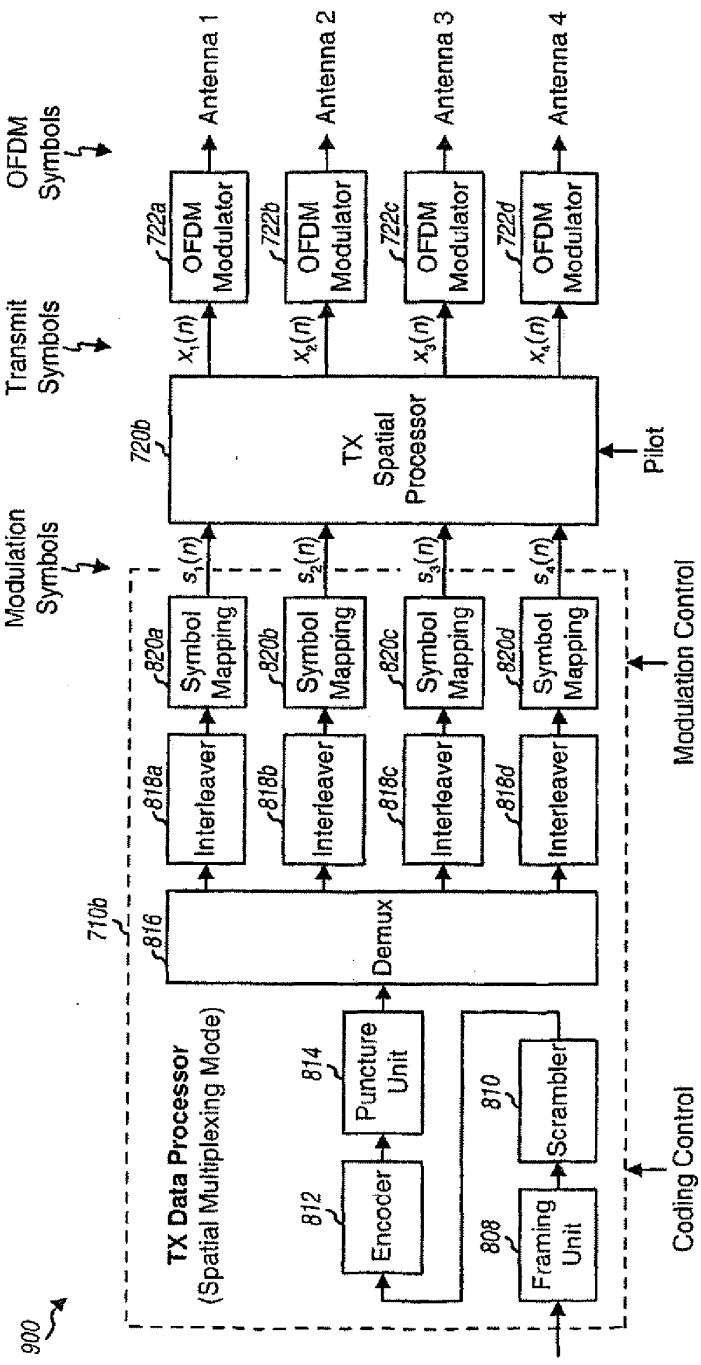

900
TX Data Processor
(Spatial Multiplexing Mode)
710b
Modulation Symbols
Transmit Symbols
OFDM Symbols
Framing Unit
808
Encoder
812
Puncture Unit
814
Scrambler
810
Demux
816
Interleaver
818a
Interleaver
818b
Interleaver
818c
Interleaver
818d
Symbol Mapping
820a
Symbol Mapping
820b
Symbol Mapping
820c
Symbol Mapping
820d
$s_1(n)$
$s_2(n)$
$s_3(n)$
$s_4(n)$
TX Spatial Processor
720b
Pilot
$x_1(n)$
$x_2(n)$
$x_3(n)$
$x_4(n)$
OFDM Modulator
722a
OFDM Modulator
722b
OFDM Modulator
722c
OFDM Modulator
722d
Antenna 1
Antenna 2
Antenna 3
Antenna 4
Coding Control
Modulation Control

FIG. 9A

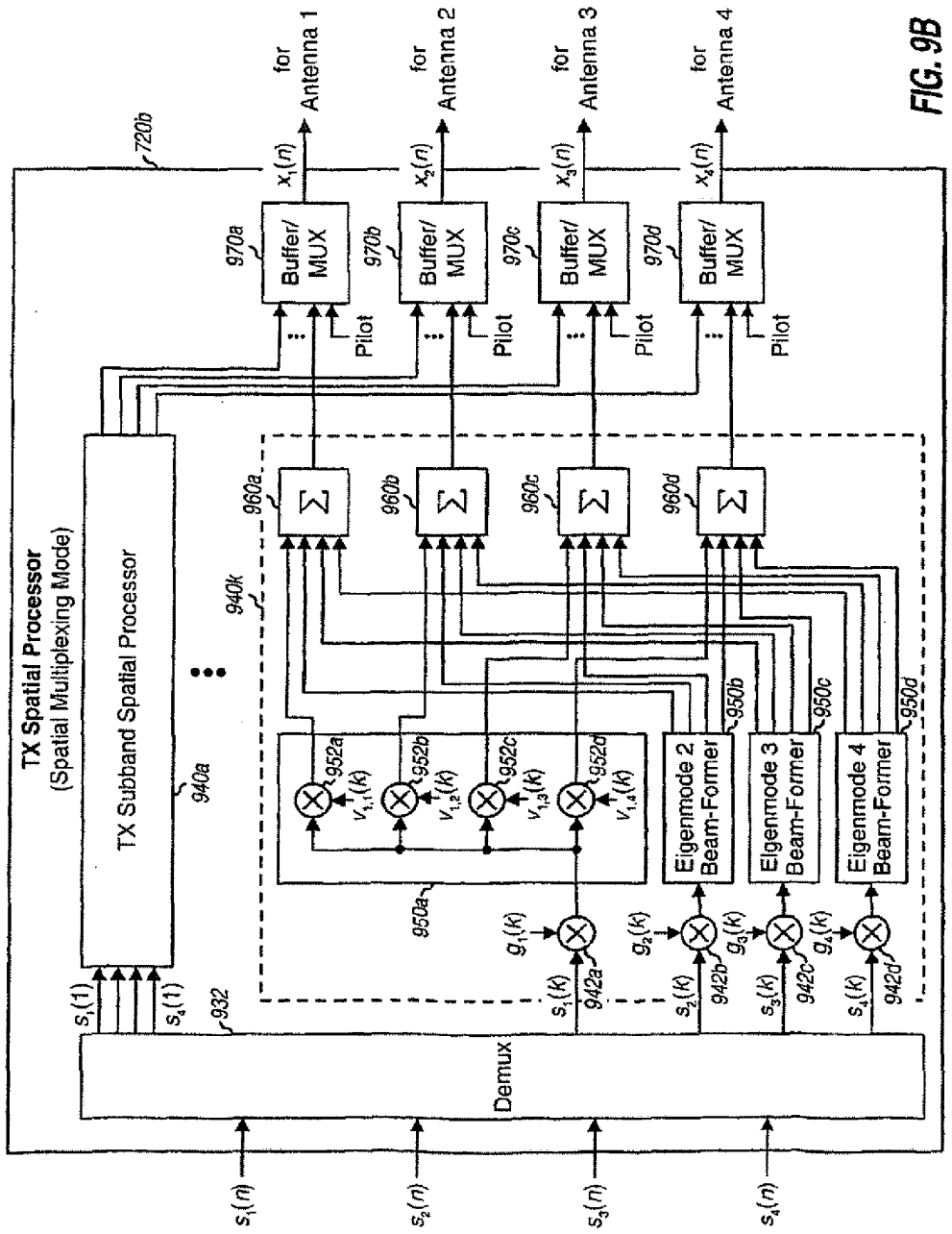

TX Spatial Processor
(Spatial Multiplexing Mode)
TX Subband Spatial Processor
Demux
Buffer/ MUX
Pilot
Eigenmode 2 Beam-Former
Eigenmode 3 Beam-Former
Eigenmode 4 Beam-Former
for Antenna 1
for Antenna 2
for Antenna 3
for Antenna 4

FIG. 9B

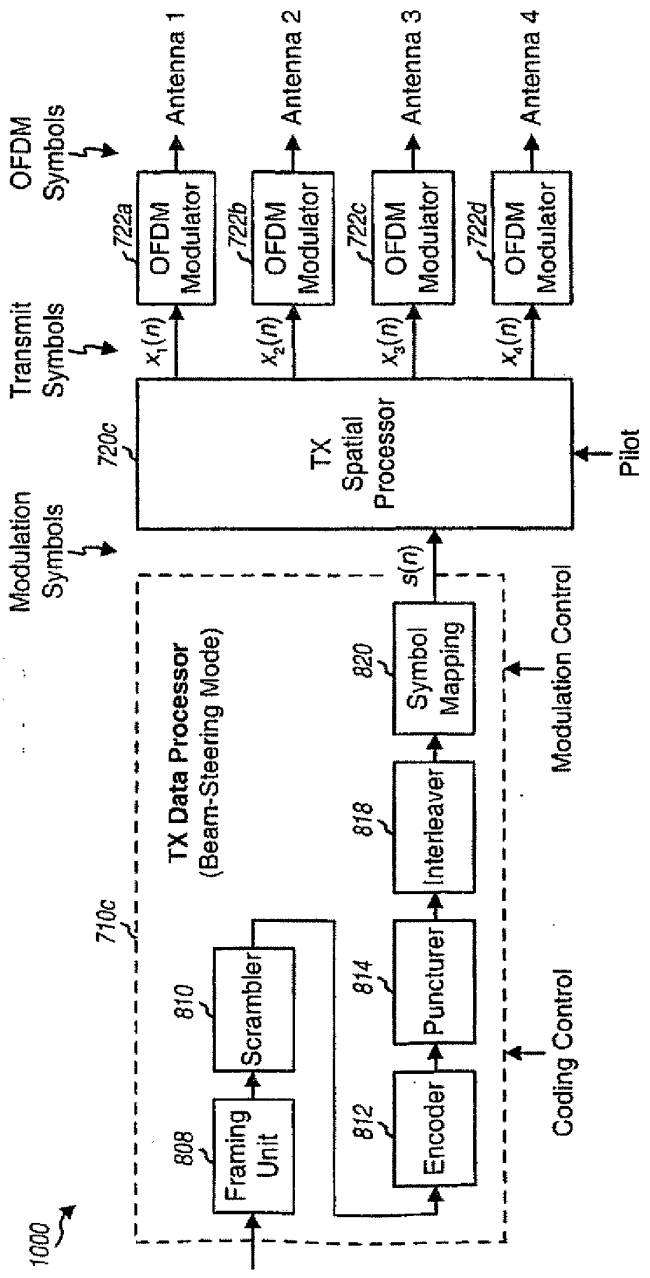

1000
710c
TX Data Processor
(Beam-Steering Mode)
Framing Unit
808
Scrambler
810
Encoder
812
Puncturer
814
Interleaver
818
Symbol Mapping
820
s(n)
Coding Control
Modulation Control
Modulation Symbols
720c
TX Spatial Processor
Pilot
Transmit Symbols
$x_1(n)$
$x_2(n)$
$x_3(n)$
$x_4(n)$
OFDM Modulator
722a
722b
722c
722d
OFDM Symbols
Antenna 1
Antenna 2
Antenna 3
Antenna 4

FIG. 10A

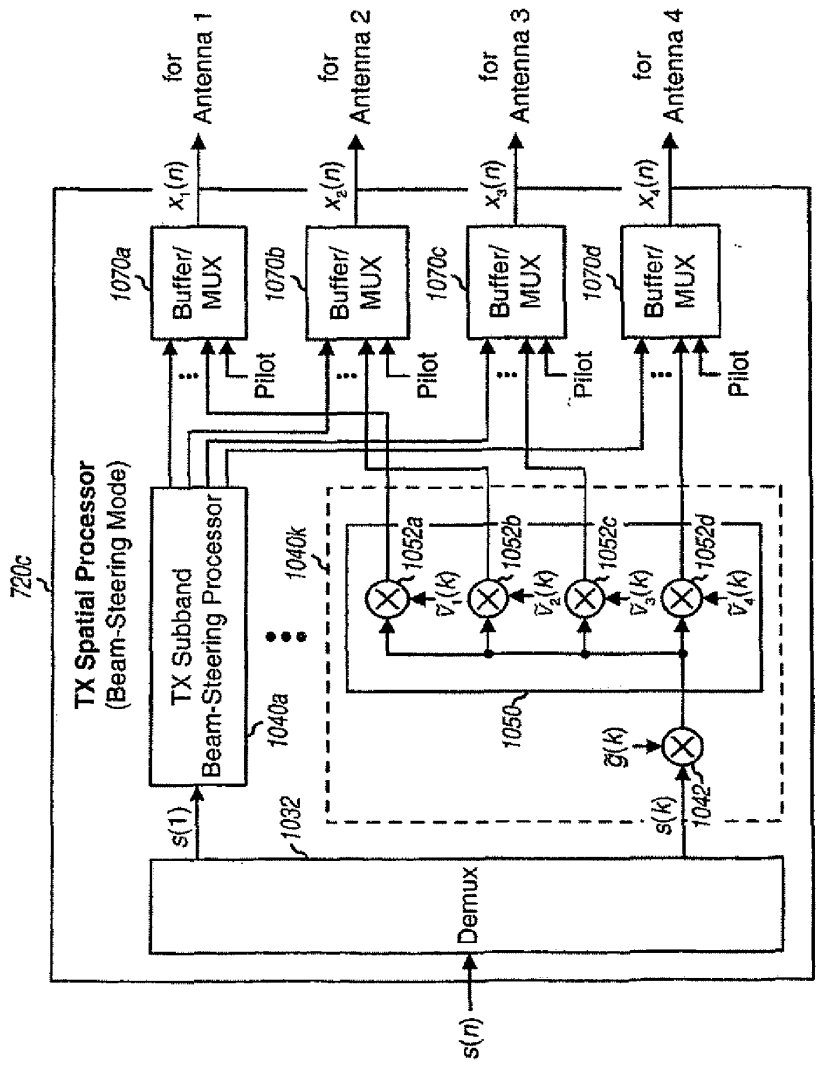

720c
TX Spatial Processor
(Beam-Steering Mode)
TX Subband
Beam-Steering Processor
1040a
1040k
1032
s(1)
Demux
s(n)
1050
1052a
1052b
1052c
1052d
g(k)
s(k)
1042
Buffer/
MUX
1070a
1070b
1070c
1070d
Pilot
for
Antenna 1
for
Antenna 2
for
Antenna 3
for
Antenna 4

FIG. 10B

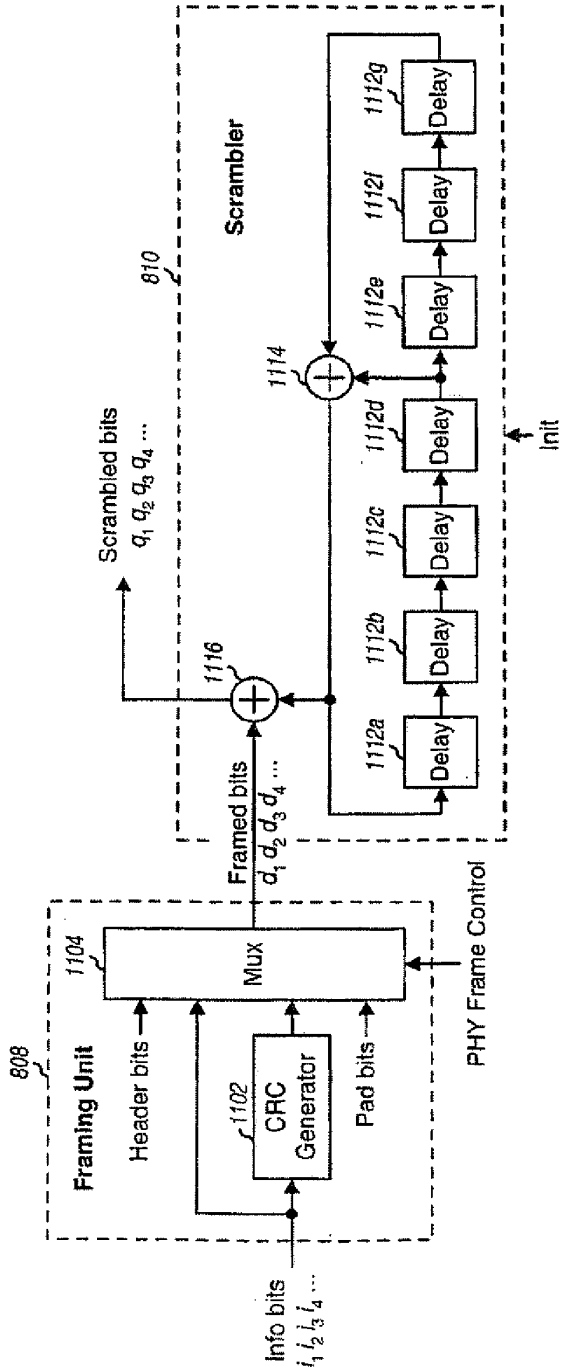

Scrambler
810
Scrambled bits
$q_1 q_2 q_3 q_4 \ldots$
1114
1112a
1112b
1112c
1112d
1112e
1112f
1112g
Delay
Init
1116
Framed bits
$d_1 d_2 d_3 d_4 \ldots$
Framing Unit
808
1104
Mux
Header bits
Pad bits
1102
CRC Generator
PHY Frame Control
Info bits
$i_1 i_2 i_3 i_4 \ldots$

FIG. 11A

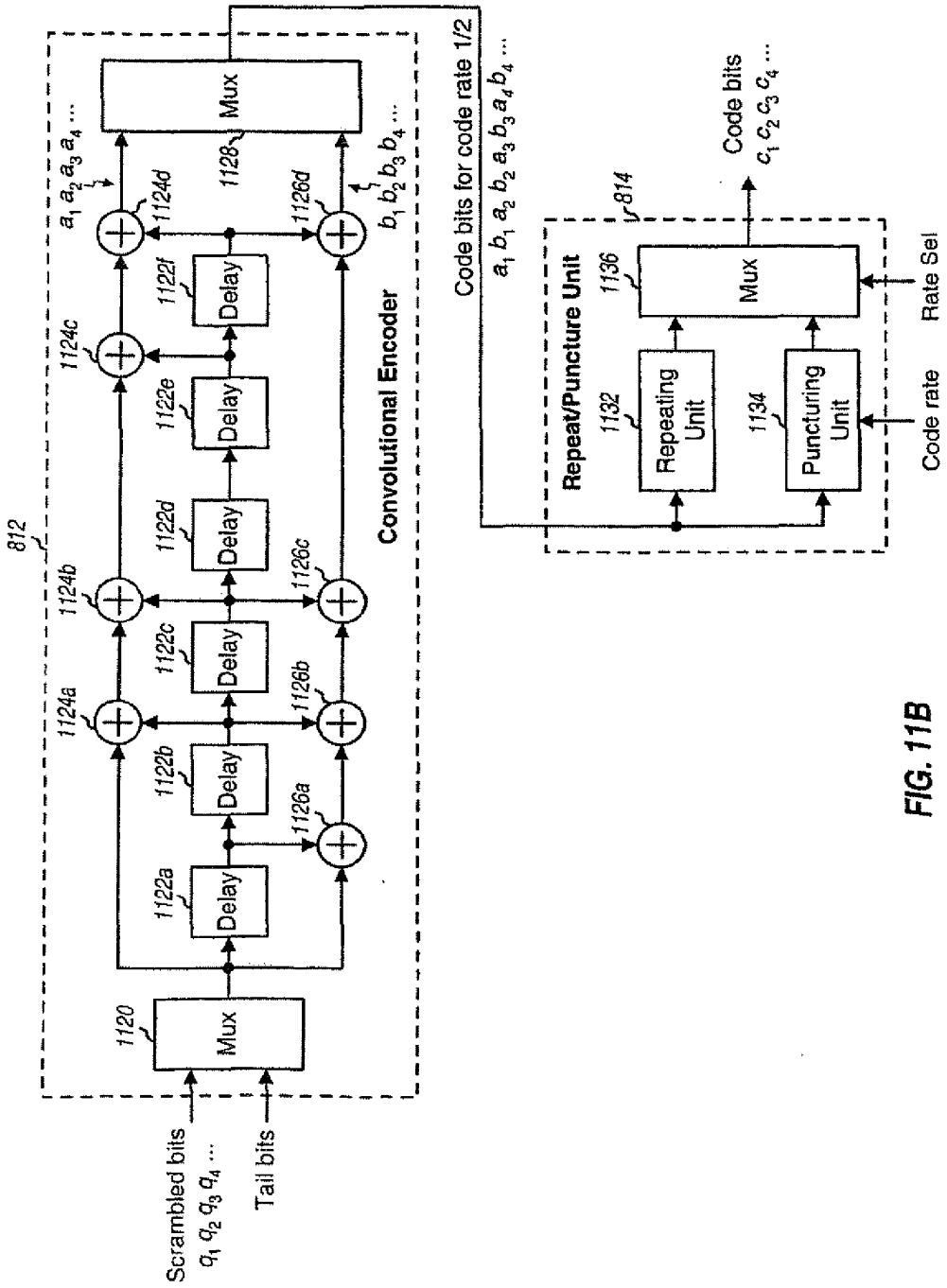

812
Convolutional Encoder
1120
Mux
1122a
Delay
1122b
Delay
1122c
Delay
1122d
Delay
1122e
Delay
1122f
Delay
1124a
1124b
1124c
1124d
1126a
1126b
1126c
1126d
1128
Mux
Scrambled bits
$q_1 q_2 q_3 q_4 \ldots$
Tail bits
$a_1 a_2 a_3 a_4 \ldots$
$b_1 b_2 b_3 b_4 \ldots$
Code bits for code rate 1/2
$a_1 b_1 a_2 b_2 a_3 b_3 a_4 b_4 \ldots$
814
Repeat/Puncture Unit
1132
Repeating Unit
1134
Puncturing Unit
1136
Mux
Code rate
Rate Sel
Code bits
$c_1 c_2 c_3 c_4 \ldots$

FIG. 11B

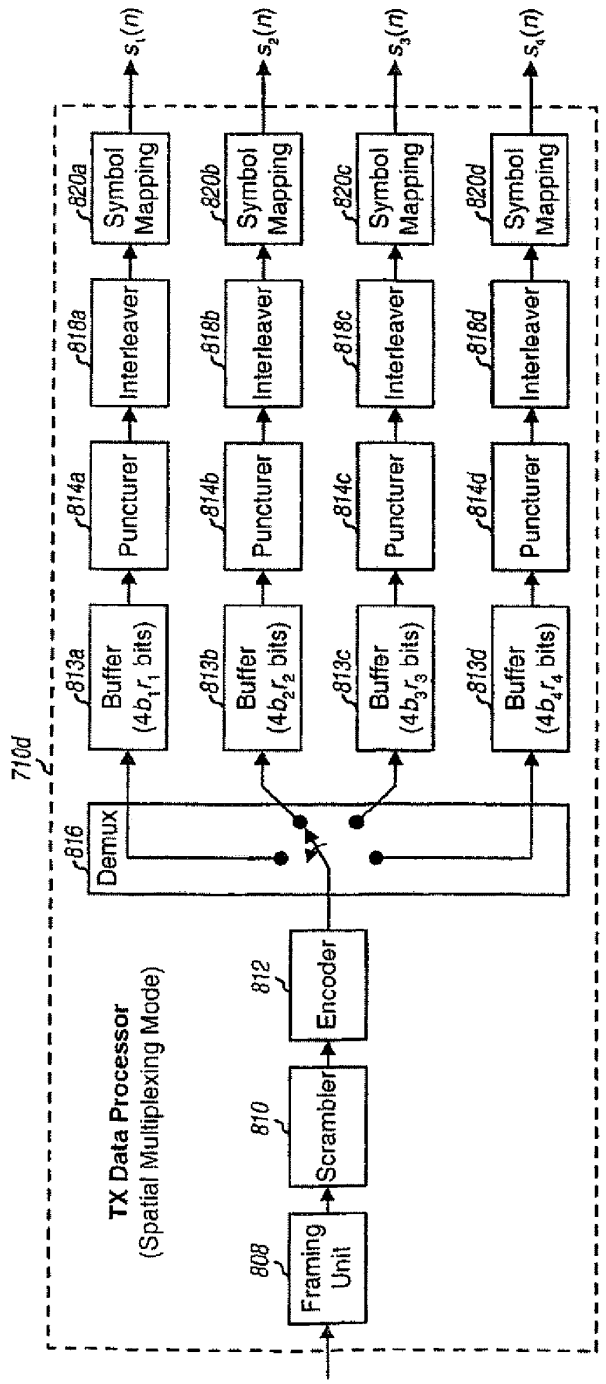

710d
TX Data Processor
(Spatial Multiplexing Mode)
808
Framing Unit
810
Scrambler
812
Encoder
816
Demux
813a
Buffer ($4b_1r_1$ bits)
813b
Buffer ($4b_2r_2$ bits)
813c
Buffer ($4b_3r_3$ bits)
813d
Buffer ($4b_4r_4$ bits)
814a
Puncturer
814b
Puncturer
814c
Puncturer
814d
Puncturer
818a
Interleaver
818b
Interleaver
818c
Interleaver
818d
Interleaver
820a
Symbol Mapping
820b
Symbol Mapping
820c
Symbol Mapping
820d
Symbol Mapping
$s_1(n)$
$s_2(n)$
$s_3(n)$
$s_4(n)$

FIG. 11C

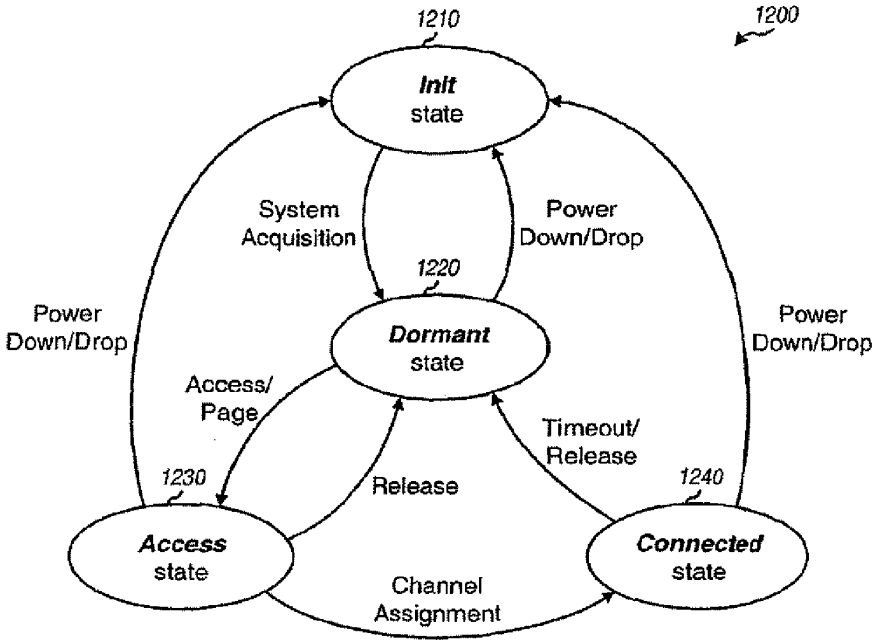


FIG. 12A

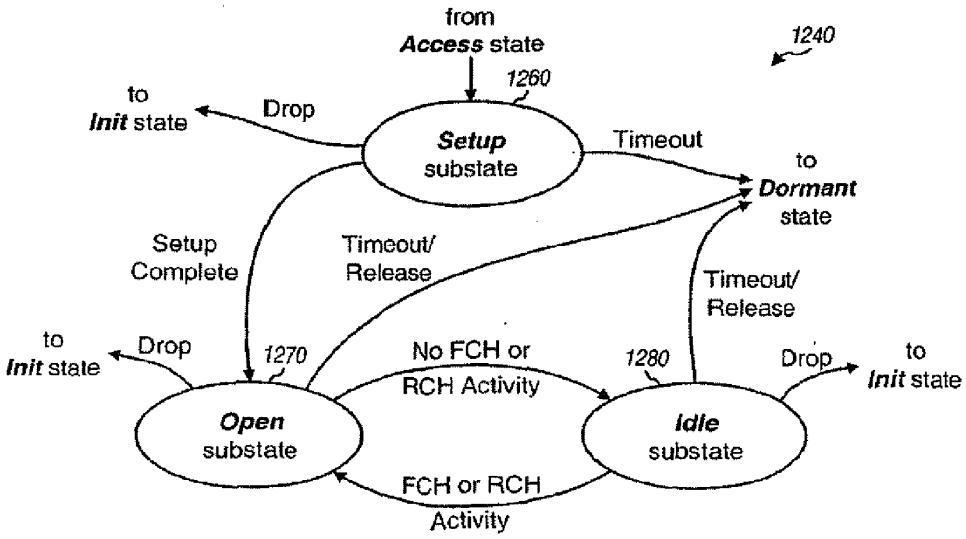


FIG. 12B

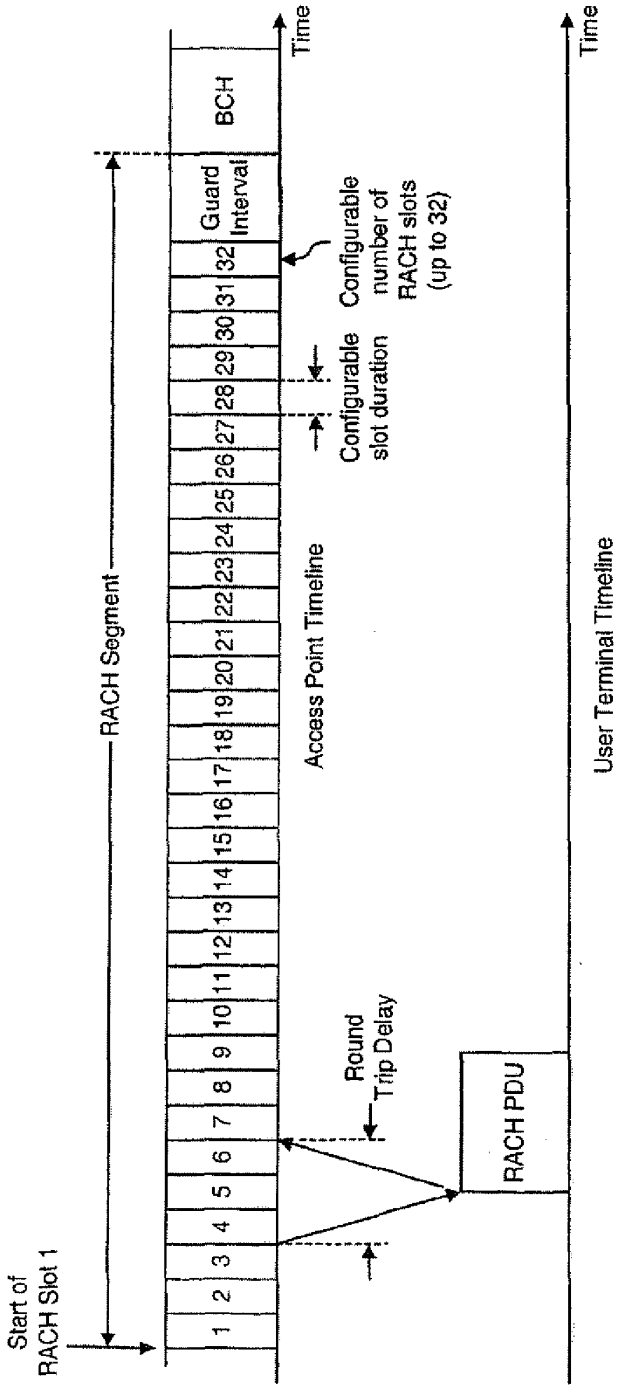

Start of RACH Slot 1
RACH Segment
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Guard Interval
BCH
Time
Access Point Timeline
Configurable slot duration
Configurable number of RACH slots (up to 32)
Round Trip Delay
RACH PDU
User Terminal Timeline
Time

FIG. 13

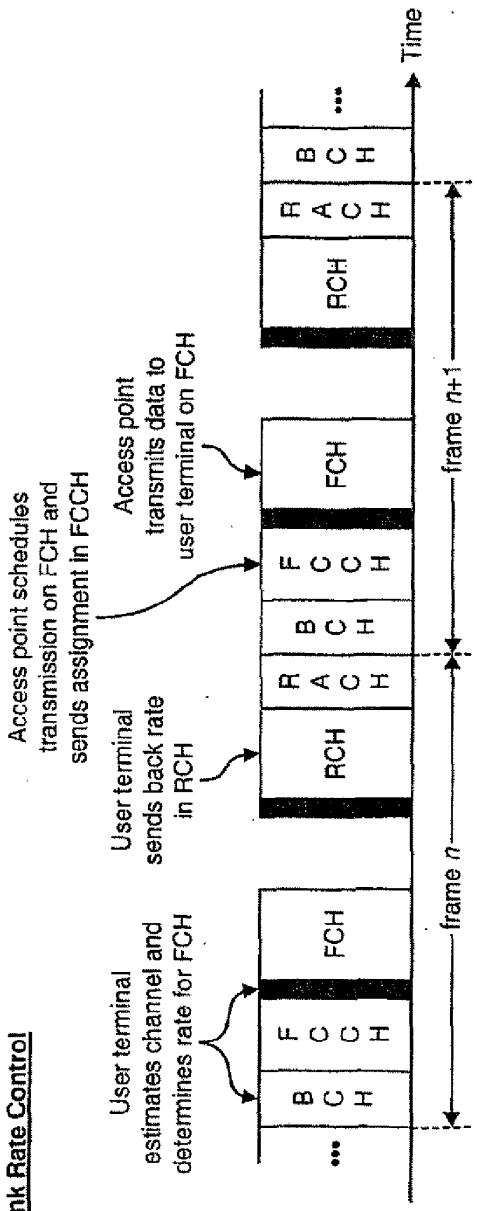


FIG. 14A

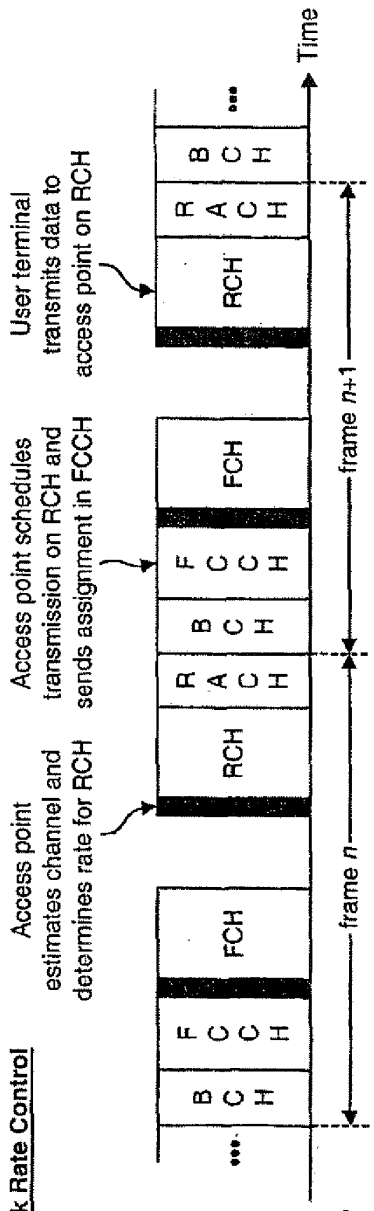


FIG. 14B

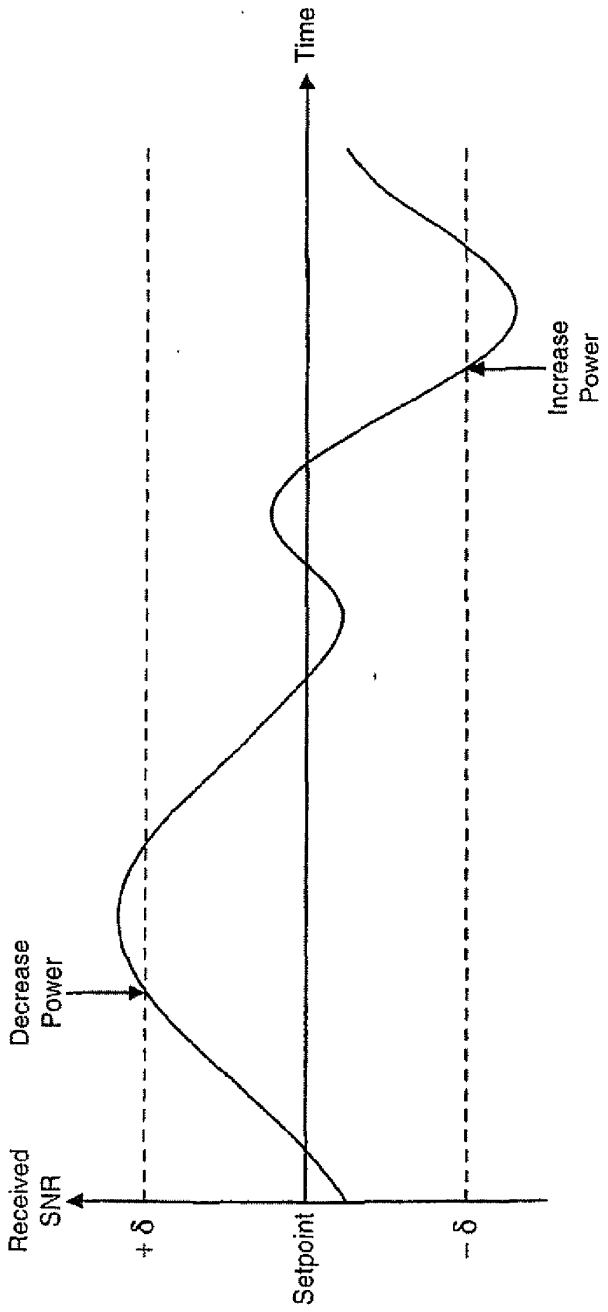

Time
Increase Power
Decrease Power
Received SNR
+ δ
Setpoint
– δ

FIG. 15

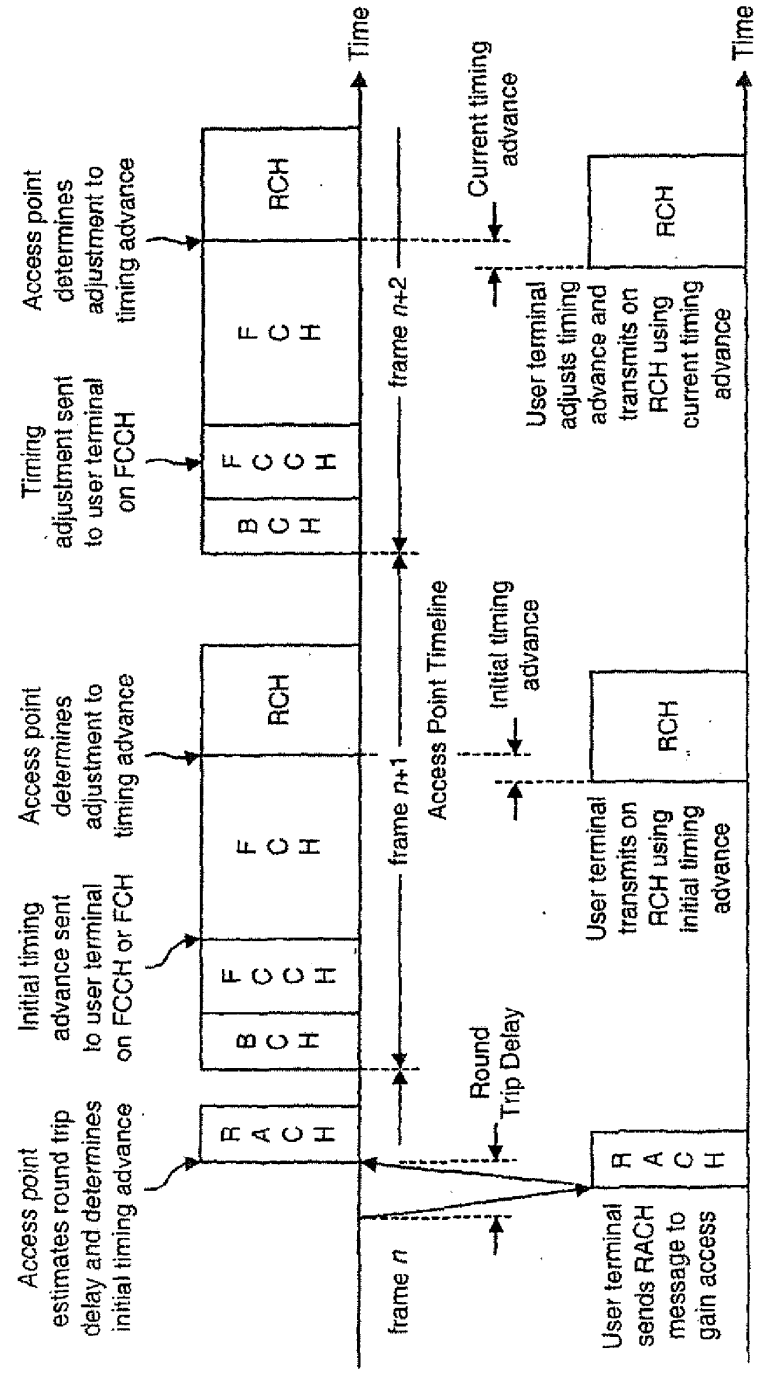

Access point estimates round trip delay and determines initial timing advance
Initial timing advance sent to user terminal on FCCH or FCH
Access point determines adjustment to timing advance
Timing adjustment sent to user terminal on FCCH
Access point determines adjustment to timing advance
RACH
BCCH
FCCH
RCH
Time
frame n
frame n+1
frame n+2
Round Trip Delay
Access Point Timeline
Initial timing advance
Current timing advance
User terminal sends RACH message to gain access
User terminal transmits on RCH using initial timing advance
User terminal adjusts timing advance and transmits on RCH using current timing advance
User Terminal Timeline

FIG. 16

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 01 9630

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 02/078211 A (QUALCOMM INCORPORATED) 3 October 2002 (2002-10-03) * abstract * * paragraphs [1019] - [1025], [1032] * * paragraphs [1056], [1057] *	1-19	H04L12/28
A	US 5 509 003 A (SNIJDERS ET AL) 16 April 1996 (1996-04-16) * column 2, line 5 - line 22 * * column 4, line 4 - line 65; claims 1,2 *	1-19	
A	TUJKOVIC D ED - INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS: "High bandwidth efficiency space-time turbo coded modulation" ICC 2001. 2001 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS. CONFERENCE RECORD. HELSINKY, FINLAND, JUNE 11 - 14, 2001, IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NEW YORK, NY : IEEE, US, vol. VOL. 1 OF 10, 11 June 2001 (2001-06-11), pages 1104-1109, XP010553500 ISBN: 0-7803-7097-1 * par. II *	1-19	

TECHNICAL FIELDS SEARCHED (IPC)

H04B
H04L
H04Q
H01Q
H04J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 November 2005	Falò, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 01 9630

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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16-11-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 1371147 A2	17-12-2003
		JP 2005502223 T	20-01-2005
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		DE 69423546 T2	21-09-2000
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 681 780 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.07.2006 Bulletin 2006/29

(51) Int Cl.:
H04B 7/005 *(2006.01)*

(21) Application number: **05252610.0**

(22) Date of filing: **27.04.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR LV MK YU

(30) Priority: **14.01.2005 JP 2005007508**

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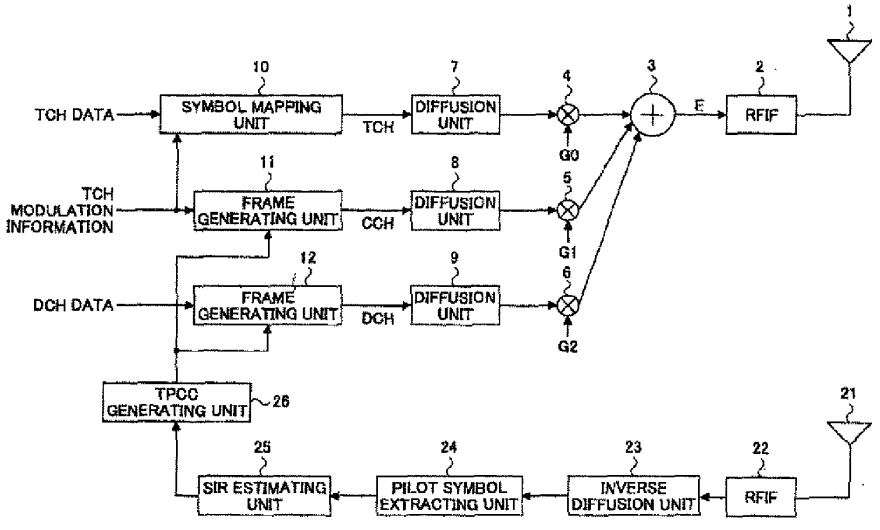
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(54) Mobile wireless communication system and wireless communication apparatus

(57) A mobile wireless communication system including a wireless communication apparatus and a counterpart wireless communication apparatus is provided, the system establishing wireless communication between the wireless communication apparatus and the counterpart wireless communication apparatus by multiplexing (3, 44) plural channels including at least a traffic channel (TCH) for transmitting a packet, a control channel (CCH) for transmitting control information for receiving the packet, and a channel (DCH) for transmitting information including transmission power control information. The wireless communication apparatus includes a transmission unit (1) that transmits the transmission control information to the counterpart wireless communication apparatus via the channel for transmitting information including transmission power control information at intervals of a prescribed period that is longer than a length of the packet, and transmits the transmission power control information via the control channel when the packet is being transmitted via the traffic channel.

FIG.3



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a mobile wireless communication system and a wireless communication apparatus that establishes wireless communication by controlling transmission power according to transmission power control information.

2. Description of the Related Art

[0002] A mobile wireless communication system that establishes wireless communication between wireless communication apparatuses such as a mobile station and a base station may have a configuration as is shown in FIG.1. The mobile wireless communication system of FIG.1 includes plural base stations 50a and 50b as wireless communication apparatuses that are located in different areas, and a mobile station 50c that conducts wireless communication while moving within the service areas of the base stations 50a and 50b. The base stations 50a and 50b and the mobile station 50c include antennas 51a, 51b, and 51c, transmission/reception units53a, 53b, and 53c that include amplifiers, modulators, and demodulators, for example, and signal processing units 54a, 54b, and 54c, respectively. Also, the base stations 50a and 50b include interface units 52a and 52b, respectively, that form interfaces with a network (not shown).

[0003] The wireless communication scheme used in the wireless communication between the mobile station 50c and the base stations 50a and 50b may correspond to the W-CDMA (Wide-Code Division Multiple Access) scheme, the OFDM (Orthogonal Frequency Division Multiplexing) scheme, or other various schemes. Also, it is noted that transmission power control (TPC) information is transmitted from the base stations 50a and 50b to the mobile station 50c at predetermined intervals via downlink channels (dedicated channels) so that a signal transmitted from the mobile station 50c to the base stations 50a and 50b may be received with a suitable power that is sufficient for proper signal reception but is below a level that may cause interference with other channels. Based on the transmission power control information, the mobile station 50c conducts transmission power control to increase/decrease the transmission power of the transmission/reception unit 53c. The transmission power control information is generated according to the reception level (quality) of a signal such as a pilot signal that is transmitted from the mobile station 50c. For example, when the reception level (quality) is high, control information directing a decrease of the transmission power may be generated, and when the reception level (quality) is low, control information directing an increase of the transmission power may be generated.

[0004] In a mobile wireless communication system that realizes packet communication, an ACK signal is transmitted when a packet is properly received, and a NACK signal is transmitted when a packet cannot be properly received, the signals being transmitted via a dedicated channel. In such a system, even when packet transmission is rarely conducted, and transmission of reception response signals such as ACK and NACK signals is not necessary, a signal such as a pilot signal is continually transmitted via another dedicated channel for suitably adjusting the transmission power of the dedicated channel used for transmitting the reception response signals such as ACK and NACK signals. Thus, the mobile station unnecessarily consumes power for transmitting such signals.

[0005] In the W-CDMA scheme, HSDPA (High Speed Downlink Packet Access) for realizing a maximum downlink transmission speed of 14 Mbps is defined. According to this scheme, adaptive coding modulation is used for packet transmission. For example, QPSK (Quadrature Phase Shift Keying) modulation and 16-QAM (Quadrature Amplitude Modulation) may be adaptively interchanged to realize a transmission rate in accordance with the state of the wireless propagation path.

[0006] It is noted that HSDPA uses the H-ARQ (Hybrid Automatic Repeat Request) scheme. For example, in the mobile wireless communication system of FIG.1, when the mobile station 50c receives packet data from the base station 50a and detects an error, the mobile station 50c sends a request to the base station 50a to retransmit the packet data. In turn, the base station 50a conducts retransmission of the packet data, and the mobile station 50c conducts an error correction decoding process using both the initially received data and the retransmitted data.

[0007] Also, it is noted that wireless channels such as HS-SCCH (High Speed-Shared Control Channel), HS-PDSCH (High Speed-Physical Downlink Shared Channel), and HS-DPCCH (High Speed-Dedicated Physical Control Channel) are used in HSDPA.

[0008] The wireless channels HS-SCCH and HS-PDSCH in a mobile wireless communication system correspond to downlink shared channels from the base station to the mobile station. The HS-SCCH corresponds to a control channel for transmitting parameter information pertaining to data transmitted by the HS-PDSCH. The parameter information may include modulation type information indicating the modulation method used in transmitting data via the HS-PDSCH, the diffusion code number, and pattern information for a rate matching process that is conducted on transmission data, for example.

[0009] The HS-DPCCH in the mobile wireless communication system corresponds to an uplink dedicated control channel from the mobile station to the base station, and is used upon transmitting from the mobile station to the base station an ACK signal or a NACK signal indicating whether data received via the HS-PDSCH are properly received. For example, in a case where CRC error is detected in the received data, a NACK signal is transmitted to the base station, and the base station con-

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ducts retransmission of the data in response to the NACK signal. Also, the HS-DPCCH is used to measure the reception quality (e.g. , SIR: Signal to Interference Ratio) of a signal received from the base station, and periodically transmit the measurement result to the base station as a CQI (Channel Quality Indicator). The base station determines the state of the downlink wireless environment based on the CQI, and when it is determined that the wireless environment is in a good state, the base station switches to a modulation method that enables data transmission at a higher speed. On the other hand, when it is determined that the wireless environment is not in a good state, the base station switches to a modulation method that realizes data transmission at a lower speed.

[0010] FIG.2 is a diagram showing the channels used in HSDPA. In this drawing, the wireless channels CPICH, P-CCPCH, HS-SCCH, HS-PDSCH, HS-DPCCH are shown. It is noted that the CPICH (Common Pilot Channel) and the P-CCPCH (Primary Common Control Physical Channel) correspond to downlink shared channels. The CPICH corresponds to a channel used for channel estimation and cell search at the mobile station, and as a timing reference of other downlink physical channels within the same cell; that is, the CPICH corresponds to a channel for transmitting the so-called pilot signal. The P-CCPCH corresponds to a channel for transmitting report information. The channels HS-SCCH, HS-PDSCH, and HS-DPCCH correspond to control channels as described above, and the HS-DPCCH is used to transmit the CQI and ACK/NACK signals.

[0011] In the illustrated example of FIG.2, 15 slots make up one frame (10 ms), and since the CPICH is used as a timing reference, the beginning (head) of the frames of the channels P-CCPCH and HS-SCCH correspond to the beginning (head) of the frame of CPICH; however, the beginning (head) of the frame of the HS-PDSCH is delayed by two slots. Such a delay is made so that the mobile station may receive and identify information pertaining to demodulation of the HS-PDSCH beforehand. That is, information pertaining to the modulation method and diffusion code is provided beforehand via the HS-SCCH so that demodulation and decoding of the HS-PDSCH may be suitably realized. Also, it is noted that in the channels HS-SCCH and HS-PSDCH, three slots make up one sub frame.

[0012] According to 3GPP TS 25.212 v.5.7.0 (3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Multiplexing and Channel Coding (FDD)), the HS-SCCH represents the following information items:

(a) Xccs (Channelization Code Set Information); 7 bits; information on the diffusion code used for the HS-PDSCH;
(b) Xms (Modulation Scheme Information); 1 bit; modulation method used for the HS-PDSCH;
(c) Xtbs (Transport-Block Size Information) ; 6 bits; transmission data block size for error correction coding;
(d) Xhap (Hybrid-ARQ Process Information); 3 bits; process number for conducting retransmission control;
(e) Xrv (Redundancy and Constellation Version); 3 bits; parameter for rate matching;
(f) Xnd (New Data Indicator); 1 bit; information indicating whether data corresponds to new data; and
(g) Xue (UE Identity); 16 bits; user identification information.

[0013] As can be appreciated from the above descriptions, the HS-SCCH is made up of 37 bits, and by receiving the HS-SCCH, parameter information pertaining to the modulation method, the diffusion code, and error correction, for example, may be identified. In turn, demodulation and decoding of the HS-DSCH may be conducted according to the parameter information.

[0014] The information (a) Xccs represents information on the diffusion code used in transmitting data via the HS-PDSCH. For example, Xccs may represent a combination of the multi-code number and code offset. The information (b) Xms indicates the modulation method being used, and for example, Xms may correspond to '1' or '0' depending on whether the current modulation method corresponds to QPSK modulation or 16-QAM. The information (c) Xtbs corresponds to data for calculating the data size for transmitting a sub frame of the HS-PDSCH. The information (d) Xhap represents a process number for H-ARQ, and corresponds to a consecutive number with respect to that of a previously transmitted data block. It is noted that in the case of a retransmission process, the same process number assigned to the previously transmitted data block is used.

[0015] The information (e) Xrv represents redundancy parameter or constellation parameter information in the retransmission of the HS-PDSCH. It is noted that in some cases, the parameter information may be updated upon transmission or retransmission, and in other cases, the parameter information may be left as it is. The information (f) Xnd corresponds to data indicating whether the transmitted block corresponds to a new data block or a retransmitted data block. For example, in the case of a new block, '1' and '0' may be interchanged, and in the case of a retransmitted block, the arrangement of '1' and '0' may be left unchanged. The information (g) Xue corresponds to identification information of the mobile station (user)

[0016] By receiving the HS-SCCH, parameter information pertaining to the modulation method, the diffusion code, and error correction used at the HS-PDSCH may be identified, and demodulation and decoding of the HS-PDSCH may be conducted (e.g., see "Multi-Antenna Transceiver Techniques for 3G and Beyond" by Ari Hottinen, Olav Tirkkonen, and Risto Wichman; 3GPP TS 25.211, Physical Channels and Mapping of Transport Channels onto Physical Channels (FDD), v. 5.5.0; 3GPP

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TS 25.213, Spreading and Modulation (FDD), v. 5.5.0; and 3GPP TS 25.214, Physical Layer Procedures (FDD), v. 5.7.0).

[0017] Also, to enhance the W-CDMA system, use of the F-DPCH (Fractional Dedicated Physical Channel) is proposed (e.g. see 3GPP RI-031073) . According to this technique, the same diffusion code is assigned to the pilot signals and transmission power control (TPC) information of a dedicated channel for plural users, and transmission is conducted through time division multiplexing within the same slot.

[0018] Generally, a mobile station (user) that receives data via a shared channel (traffic channel) such as the HS-PDSCH transmits traffic data via the HS-PDSCH, and thereby, data to be transmitted via the dedicated channel (e.g. , DPCH as opposed to an HS channel) are virtually non-existent at such a mobile station. Nonetheless, TPC bits and pilot signals have to be transmitted in order to conduct transmission power control, and thereby, the dedicated channel (DPCH) and the HS-PDSCH have to be connected at the same time. In this case, a code is occupied even when data transmission does not have to be conducted, and when plural mobile stations (users) in similar situations exist, a deficiency in code resources may be created. In response to such a problem, the technique implementing the F-DPCH involves using the same code to conduct a diffusion process and time division multiplexing with respect to TPC bits and pilot signals of plural users that have no transmission data to be transmitted through a dedicated channel.

[0019] Also, as another measure for countering a deficit of code resources, Japanese Laid-Open Patent Publication No. 11-145901 discloses a wireless communication apparatus that conducts transmission power control through providing a dedicated power control channel, embedding TPC bits of plural users into the transmission power control channel through time division multiplexing, and embedding identical TPC bits into traffic channels for conducting packet transmission, wherein when a packet to be transmitted is generated, the TPC bits of the power control channel is converted into invalid information so that the TPC bits of the traffic channel is prioritized.

[0020] In the W-CDMA scheme, transmission power control (TPC) of a dedicated channel (DPCH) is conducted via an uplink channel. The transmission power control (TPC) involves controlling the transmission power of the mobile station by feeding back transmission control information referred to as TPC bits in slot units from the base station to the mobile station. On the other hand, in a packet communication scheme using shared channels such as the HS-PDSCH, pilot signals and TPC bits are periodically transmitted via uplink and downlink DPCH channels so that transmission power for transmitting a reception response signal is adjusted to a suitable level at a mobile station even when data are not addressed to the mobile station. In such a case, code resources have to be used for transmission power control of the respective dedicated channels, and thereby, a deficiency in code resources is created. Also, since the mobile station has to transmit pilot signals on a constant basis, a large amount of power is consumed as a result.

[0021] Also, a technique is proposed in the prior art that uses the F-DPCH in the W-CDMA scheme to integrate plural A-DPCH channels through time division multiplexing for realizing efficient use of code resources. However, since transmission power control (TPC) bits are transmitted in slot units, multiplexing may not be conducted for a large number of users. That is, according to this technique, a large number of mobile stations conducting packet transmission cannot be accommodated within the same area. Also, according to this technique, it is assumed that a signal is transmitted on a constant basis via the uplink channel. That is, the mobile station is arranged to transmit a signal such as a pilot signal for realizing transmission power control regardless of whether packet transmission is conducted. This arrangement is disadvantageous from the point of view of power conservation. It is noted that the mobile station uses a relatively small battery as a power source to conduct transmission/reception processes, and thereby, it is desired that power consumption be reduced in order to realize packet transmission for a long period of time.

[0022] Also, in the prior art technique involving the use of a power control channel and a traffic channel for transmitting TPC bits, when the TPC bits are transmitted via the traffic channel, the TPC bits at the power control channel have to be invalidated in order to prevent generation of a conflict. Such processes may be quite complicated thereby leading to high power consumption. Also, since the power control channel is arranged to be transmitted when a transmission control packet does not exist and is therefore not transmitted on a periodic basis, power control may not be stabilized.

SUMMARY OF THE INVENTION

[0023] The present invention has been conceived in response to one or more of the problems of the related art, and its object is to enable transmission power control with low power consumption and high accuracy.

[0024] According to an aspect of the present invention, a mobile wireless communication system is provided that includes:

a wireless communication apparatus and a counterpart wireless communication apparatus; wherein wireless communication is established between the wireless communication apparatus and the counterpart wireless communication apparatus by multiplexing a plurality of channels including at least a traffic channel for transmitting a packet, a control channel for transmitting control information for receiving the packet, and a channel for transmitting information including transmission power control information; and

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the wireless communication apparatus includes a transmission unit that transmits the transmission control information to the counterpart wireless communication apparatus via the channel for transmitting information including transmission power control information at intervals of a prescribed period that is longer than a length of the packet, and transmits the transmission power control information via the control channel when the packet is being transmitted via the traffic channel.

[0025] In a preferred embodiment of the present invention, the counterpart wireless communication apparatus includes a transmission unit that transmits a pilot signal right before receiving the transmission power control information transmitted from the wireless communication apparatus via the channel for transmitting information including transmission power control information and right after receiving the transmission power control information transmitted from the wireless communication apparatus via the control channel.

[0026] In another preferred embodiment of the present invention, the transmission power control information transmitted from the wireless communication apparatus to the counterpart wireless communication apparatus includes first transmission power control information that is transmitted via the channel for transmitting information including transmission power control information and second transmission power control information that is transmitted via the control channel, and the transmission unit of the counterpart wireless communication apparatus transmits the pilot signal at periodic intervals shorter than a transmission period at which the first transmission power control information is transmitted.

[0027] In another preferred embodiment of the present invention, the transmission power control information transmitted from the wireless communication apparatus to the counterpart wireless communication apparatus includes first transmission power control information that is transmitted via the channel for transmitting information including transmission power control information and second transmission power control information that is transmitted via the control channel, and a transmission power control level represented by the second transmission power control information is arranged to be greater than or equal to a transmission power control level represented by the first transmission power control information.

[0028] According to another aspect of the present invention, a wireless communication apparatus is provided that is configured to transmit data within a mobile wireless communication system that realizes data transmission via a shared channel, the apparatus including:

a transmission unit that is configured to transmit to a mobile station first transmission power control information at intervals of a prescribed period, and transmit control information for receiving the data including second transmission power control information when transmitting the data to the mobile station.

[0029] In a preferred embodiment of the present invention, a transmission power control level represented by the second transmission power control information that is included in the control information is arranged to be greater than or equal to a transmission power control level represented by the first transmission power control information that is transmitted at intervals of the prescribed period.

[0030] According to another aspect of the present invention, a wireless communication apparatus is provided that is configured to receive data within a mobile wireless communication system that realizes data transmission via a shared channel, the apparatus including:

a transmission unit that is configured to transmit a pilot signal in conjunction with receiving control information for receiving the data.

[0031] In a preferred embodiment of the present invention, the transmission unit is further configured to transmit the pilot signal at intervals of a prescribed period, and the transmission of the pilot signal in conjunction with the reception of the control information is conducted at periodic intervals shorter than the prescribed period.

[0032] According to an aspect of the present invention, transmission power control information is transmitted at prescribed periodic intervals via a channel for transmitting information including the transmission power control information, and when packet transmission is conducted, transmission power control information is also transmitted via a control channel. When packet transmission is not conducted, the transmission power control information is transmitted via the channel for transmitting information including transmission power control information at prescribed periodic intervals that are set to be relatively long, thereby enabling conservation of power. According to an embodiment of the present invention, a pilot signal is transmitted at prescribed periodic intervals rather than being continuously transmitted, and the packet signal is also transmitted upon indicating the presence of a packet for transmission to thereby enable further power conservation. According to an embodiment of the present invention, the transmission power control information includes first transmission power control information that is transmitted via the channel for transmitting information including transmission power control information and second transmission power control information that is transmitted via the control channel, and a transmission power control level represented by the second transmission power control information is arranged to be greater than that represented by the first transmission power control information to improve responsiveness of the transmission power control operation.

[0033] According to another aspect of the present invention, by transmitting the transmission power control

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information at prescribed periodic intervals, the transmission power control information may be included in the control information for receiving data while maintaining stability in the transmission power control operation, and the transmission power control information may be transmitted in conjunction with data transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

FIG.1 is a diagram showing a configuration of a mobile wireless communication system;
FIG.2 is a diagram showing channels used in HSDPA;
FIG.3 is a diagram showing a configuration of a wireless communication apparatus according to an embodiment of the present invention;
FIG.4 is a diagram showing a configuration of a counterpart wireless communication apparatus according to an embodiment of the present invention;
FIG.5 is a diagram illustrating a transmission power control operation according to a first embodiment of the present invention; and
FIG.6 is a diagram illustrating a transmission power control operation according to a second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] In the following, preferred embodiments of the present invention are described with reference to the accompanying drawings.

[0036] A mobile wireless communication system according to an embodiment of the present invention includes a wireless communication apparatus such as a base station and a counterpart wireless communication apparatus such as a mobile station, and is arranged to establish wireless communication between the wireless communication apparatus and the counterpart wireless communication apparatus by multiplexing a plurality of channels including at least a traffic channel for transmitting a packet, a control channel for transmitting control information for receiving the packet, and a channel for transmitting information including transmission power control information. In such a system, the wireless communication apparatus corresponding to a base station, for example, is arranged to include a transmission unit that transmits the transmission control information to the counterpart wireless communication apparatus corresponding to the mobile station, for example, via the channel for transmitting information including transmission power control information at intervals of a prescribed period that is longer than the length of the packet, and transmits the transmission power control information via the control channel when the packet is being transmitted via the traffic channel.

[0037] A wireless communication apparatus according to an embodiment of the present invention corresponds to a wireless communication apparatus such as a base station of a mobile wireless communication system, and includes a transmission unit that is configured to transmit to a mobile station via a dedicated channel first transmission power control information at intervals of a prescribed period that is longer than a length of a packet transmitted by a traffic channel, and transmit second transmission power control information via a control channel when transmitting the packet via the traffic channel.

[0038] It is noted that the transmission power control information in the following descriptions is assumed to be. valid information (to be used at the reception side)o

[0039] FIG.3 is a diagram showing an exemplary configuration of a wireless communication apparatus according to an embodiment of the present invention. The wireless communication apparatus of FIG.3 may correspond to a wireless communication apparatus such as a base station of a mobile wireless communication system implementing the CDMA scheme that includes at least a wireless communication apparatus and a counterpart wireless communication apparatus. According to the present example, the wireless communication apparatus includes antennas 1 and 21, a high frequency processing unit (RFIF) 2, a multiplexing unit 3, multiplying units 4, 5, and 6, diffusion units 7, 8, and 9, a symbol mapping unit 10, frame generating units 11 and 12, a high frequency processing unit (RFIF) 22, an inverse diffusion unit 23, a pilot symbol extracting unit 24, a SIR (Signal to Interference Ratio) estimating unit 25, and a TPCC (transmission power control information) generating unit 26. It is noted that known configurations may be implemented to realize the interface with the network (in a case where the apparatus corresponds to a base station) and generation processing units for generating TCH data, TCH modulation information, and DCH data, and thereby, such components are omitted from the present drawing.

[0040] According to the present embodiment, the high frequency processing unit 2 that is connected to the antenna 1 includes an encoder, a modulator, and an amplifier, for example. The high frequency processing unit 22 that is connected to the antenna 21 includes a low noise amplifier, a demodulator, and a decoder, for example. Also, TCH (traffic channel such as HS-PDSCH) data are input to the symbol mapping unit 10, TCH modulation information (e.g., information to be transmitted via the HS-SCCH) is input to the symbol mapping unit 10 and the frame generating unit 11, and DCH (dedicated channel such as DPCH) data are input to the frame generating unit 12. At the symbol mapping unit 10, the TCH data are mapped according to the TCH modulation information, and input to the diffusion unit 7 as traffic channel TCH. At the diffusion unit 7, a diffusion process is conducted on the TCH using a diffusion code assigned to the TCH, and the diffused signal is input to the multiplying unit 4.

[0041] The frame generating unit 11 generates a frame including the TCH modulation information and transmis-

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sion power control information from the TPCC generating unit 26, and inputs the generated frame to the diffusion unit 8 as a control channel CCH. At the diffusion unit 8, a diffusion process is conducted using a diffusion code assigned to the control channel CCH, and the diffused signal is input to the multiplying unit 5. The frame generating unit 12 generates a frame including the DCH data and the transmission power control information from the TPCC generating unit 26, and inputs the generated frame to the diffusion unit 9 as a dedicated channel DCH. At the diffusion unit 9, a diffusion process is conducted using a diffusion code assigned to the dedicated channel, and the diffused signal is input to the multiplying unit 6. As can be appreciated from the above descriptions, in the present embodiment, the TCH data, the TCH modulation information, and the DCH data are diffused by differing diffusion codes. Also, the multiplying units 4, 5, and 6 multiply their inputs by gains G0, G1, and G2, respectively, to set the transmission power ratios of the respective channels, and at the multiplexing unit 3, multiplexing is realized by conducting adding processes on chips. The multiplexed signal is then input to the high frequency processing unit 2 at which modulation and amplification processes are conducted, and the resulting signal is transmitted via the antenna 1. It is noted that in this example, the diffusion codes used in the diffusion units 7, 8, and 9 are arranged to differ from each other.

[0042] The high frequency processing unit 22 conducts processes such as amplification, demodulation, and decoding on a signal received by the antenna 21. The inverse diffusion unit 23 receives the signal processed by the high frequency processing unit 22 and conducts an inverse diffusion process on the signal. Then, the pilot symbol extracting unit 24 receives the inverse-diffused signal and extracts a pilot symbol (e.g., upon receiving an uplink DPSCH). The SIR estimating unit 25 estimates a SIR (Signal to Interference Ratio) from plural pilot symbols, and inputs the estimated SIR value to the TPCC generating unit 26. The TPCC generating unit 26 compares the input SIR value with a threshold value, and sets the TPCC according to the comparison result. For example, when the SIR value is greater than the threshold value, the TPCC may be set to TPCC = -1 , and when the SIR value is less than the threshold value, the TPCC may be set to TPCC = +1. The TPCC is then input to the frame generating units 11 and 12 as transmission power control information. As is described below, the TPCC may also be arranged to conduct transmission power control in plural stages.

[0043] According to the present embodiment, the TCH modulation information and the transmission power control information TPCC are transmitted from the frame generating unit 11 by a control channel CCH (e.g., HS-SCCH), and the DCH data and the transmission power control information TPCC are transmitted from the frame generating unit 12 by a dedicated channel DCH (e.g., DPCH). That is, the transmission power control information is transmitted by both the control channel CCH and the dedicated channel DCH. In a case where the transmission power control information TPCC is transmitted by the dedicated channel DCH at relatively long periodic intervals and packet transmission is conducted based on a signal from the control channel CCH indicating whether a packet is present, the transmission power control information TPCC is transmitted by the control channel CCH in accordance with the packet transmission timing. It is noted that the transmission of the transmission power control information as is described above may be controlled by a control unit (not shown) . The transmission of the transmission power control information TPCC according to the packet transmission timing is conducted at shorter periodic intervals compared to that for the transmission of the transmission power control information TPCC by the dedicated channel DCH. Thereby, the responsiveness of the transmission power control operation may be improved. It is noted that in one embodiment, the power control level represented by the transmission power control information transmitted by the control channel CCH may be arranged to be greater than the power control level represented by the transmission power control information transmitted by the dedicated channel DCH.

[0044] FIG. 4 is a diagram showing an exemplary configuration of a counterpart wireless communication apparatus according to an embodiment of the present invention. The counterpart wireless communication apparatus of FIG.4 may correspond to a mobile station of the mobile wireless communication system using the CDMA scheme that includes a wireless communication apparatus and a counterpart wireless communication apparatus. The counterpart wireless communication apparatus of FIG.4 includes antennas 31 and 42, a high frequency processing unit (RFIF) 32, a CCH inverse diffusion unit 33, a TCH inverse diffusion unit 34, a DCH inverse diffusion unit 35, a bit determination unit 36, a TPCC extracting unit 37, a transmission power control unit 38, a high frequency processing unit (RFIF) 42, a multiplying unit 43, a multiplexing unit 44, and diffusion units 45, 46, and 47. It is noted that known configurations may be implemented to realize processing units for processing downlink traffic data and uplink traffic data, and thereby, such components are omitted from the present drawing.

[0045] The antenna 31 receives a signal transmitted from the antenna 1 of FIG.3, for example, and inputs the received signal to the high frequency processing unit 32. The high frequency processing unit 32 includes a low noise amplifier, a demodulator and a decoder, for example. The antenna 41 is configured to transmit a signal from the high frequency processing unit 42 to the antenna 21 of FIG. 3, for example. The high frequency processing unit 42 includes an encoder, a modulator, and a transmission power amplifier, for example. The high frequency processing unit 32 demodulates and decodes a received signal and inputs the processed signal to the CCH inverse diffusion unit 33, the TCH inverse diffusion unit 34, and the DCH inverse diffusion unit 35. In turn, the CCH in-

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verse diffusion unit 33, the TCH inverse diffusion unit 34, and the DCH inverse diffusion unit 35 conduct inverse diffusion processes on the input signal using the respective diffusion codes used in the corresponding diffusion processes conducted at the transmission side.

[0046] The CCH inverse diffusion unit 33 conducts an inverse diffusion process on the CCH information that is transmitted from the transmission side, and inputs the inverse-diffused information to the bit determination unit 36. The TCH inverse diffusion unit 34 conducts an inverse diffusion process on the TCH modulation information that is transmitted from the transmission side, and inputs the inverse-diffused information to the bit determination unit 36. In turn, the bit determination unit outputs downlink traffic data. Also, inverse diffusion outputs including transmission power control information that are obtained by inverse diffusion processes conducted by the TCH inverse diffusion unit 34 and the DCH inverse diffusion unit 35, respectively, are input to the TPCC extracting unit 37 at which the transmission power control information is extracted. The extracted transmission power information is then input to the transmission power control unit 38.

[0047] Also, according to the present embodiment, uplink traffic data, a pilot symbol, and a ACK/NACK signal based on the reception processing result of processing downlink traffic data output are input to the diffusion units 45, 46, and 47, respectively, to be diffused by differing diffusion codes. Then the diffused signals are multiplexed at the multiplexing unit 44, and multiplied at the multiplying unit 43 by a control value from the transmission power control unit 38 to realize transmission power control. Then, processes such as coding, modulation and amplification are conducted by the high frequency processing unit 42, after which the processed signal is transmitted via the antenna 41. According to an embodiment, the transmission power control unit 38 is configured to increment the transmission power Ptx by +1 dB when the transmission power control information TPCC extracted by the TPCC extracting unit 37 is greater than 0 (TPCC > 0), and the transmission power control unit 38 is configured to decrement the transmission power Ptx by -1 dB when the transmission power control information is TPCC is less than 0 (TPCC <0). In this way, the transmission power control unit 38 is arranged to input a value to the multiplying unit 43 according to the updated transmission power Ptx. It is noted that the transmission power control information TPCC may be arranged to use plural bits so that transmission power control may be conducted in plural stages (i.e., so that transmission power may be increased or decreased in plural stages).

[0048] FIG. 5 is a diagram illustrating a transmission power control operation according to a first embodiment of the present invention. In this drawing, a dedicated channel DCH, a control channel CCH, a traffic channel TCH, an uplink ACK/NACK signal transmission, and an uplink pilot signal transmission are shown. In the present embodiment, the uplink pilot signal is successively transmitted irrespective of the uplink ACK/NACK transmission. It is noted that in the present drawing, the transmission power levels are represented by the relative heights of the indicated signals. Given that transmission power control information TPCC transmitted by the dedicated channel DCH is referred to as first transmission.power control information, and the transmission power control information TPCC transmitted by the control channel CCH is referred to as second transmission power-control information, the first transmission power control information includes a slot that is made up of TPCC addressed to a present mobile station (self-addressed TPCC) and TPCC addressed to another mobile station, and a slot that does not include a self-addressed TPCC. In other words, first transmission power control information TPCC that is addressed to the present mobile station is transmitted at relatively long periodic intervals which transmission period may be set in advance at the transmission side. The self-addressed TPCC that is transmitted by the control channel CCH; namely, the second transmission power control information, is transmitted in accordance with the packet transmission period, which is arranged to be shorter than the transmission period of the first transmission power control information.

[0049] As can be appreciated from the above descriptions, when packet transmission is not conducted, the first transmission power control information is transmitted at relatively long periodic intervals, and accordingly, transmission power control is conducted at relatively long periodic intervals. When packet transmission is conducted, the second transmission power control information is transmitted according to the packet transmission period, and thereby, transmission power control may be conducted at a faster pace. Thus, when packet transmission is not conducted, unnecessary transmission power control processes are omitted so that the power consumption rate may be reduced. On the other hand, when packet transmission is conducted, the first transmission power control information and the second transmission power control information are transmitted so that high-pace transmission power control may be conducted with regard to state changes such as fading occurring in the wireless propagation path.

[0050] FIG.6 is a diagram illustrating a transmission power control process according to a second embodiment of the present invention. According to the present embodiment, F-DPCH (Fractional Dedicated Physical Channel) is used. The F-DPCH is made up of slots including at least a TPC bit and a pilot signal. In this drawing, a HS-SCCH (Shared Control Physical Channel) (downlink packet control channel), a HS-PDSCH (High Speed Downlink Shared Channel) (downlink traffic channel), an uplink ACK/NACK transmission (the transmission channel corresponding to a HS-DPCCH), and an uplink pilot transmission (the transmission channel corresponding to a DPCH are shown.

[0051] The TPC bit (transmission power control information) is transmitted via the F-DPCH and HS-SCCH.

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[0052] The F-DPCH corresponds to a channel that is capable of transmitting a slot including plural TPC bits addressed to differing mobile stations. In the illustrated example, TPC bits addressed to two mobile stations are temporally multiplexed. It is noted that in this example, the transmission period of the TPC bits addressed to one mobile station (i.e., indicated as self-addressed TPC bits) is set to two slots. That is, the self-addressed TPC bit is not included in every other slot. Also, the transmission period of the TPCC addressed to another mobile station is also set to two slots in this example; however, it is noted that differing transmission periods may be set for the respective mobile stations.

[0053] The frames of the HS-SCCH are also configured to transmit TPC bits to mobile stations that are subject to control data transmission. It is noted that in the present drawing, HS-SCCH transmission to one mobile station is illustrated.

[0054] The mobile station receiving the HS-SCCH receives the HS-PDSCH and packet data, and transmits the reception result as a response signal (e.g., ACK/NACK signal) via the HS-DPCCH. According to the present example, the HS-PDSCH is received three times, and the ACK/NACK signal is transmitted after the elapse of a predetermined time from the channel reception timing, taking into account factors such as reception processing delay.

[0055] The pilot signal is transmitted in conjunction with the transmission period of the first transmission power control information (self-addressed TPCC), and is transmitted before the transmission timing of the first transmission power control information. It is noted that such a transmission power control may be realized by a control unit (not shown) according to the timing of inputting the pilot symbol to the diffusion unit 46 of the wireless communication apparatus shown in FIG.4, for example.

[0056] That is, a self-addressed TPCC is periodically transmitted, and in order to generate such transmission power control information, a known signal (pilot signal) is transmitted from the mobile station before the self-addressed TPCC is transmitted (i.e., prior to the TPCC transmission by a predetermined time period so as to be in time for the TPC bit generation).

[0057] The pilot signal is also transmitted in conjunction with the transmission of control information and ACK/NACK signals that are transmitted via the HS-SCCH.

[0058] That is, when a mobile station recognizes that data is being transmitted to itself via the HS-SCCH, or when it receives data addressed to itself via the HS-PDSCH, it transmits a known signal (pilot signal) upon transmitting an ACK signal or a NACK signal.

[0059] It is noted that the reception of the HS-PDSCH and the transmission of the ACK/NACK signal are conducted in conjunction with the reception of the HS-SCCH, and thereby, in either case, the known signal is transmitted in conjunction with the reception of the HS-SCCH.

[0060] According to the present embodiment, the wireless communication apparatus as is shown in FIG.3 that may correspond to a base station receives a pilot signal, conducts SIR estimation on the pilot signal at the SIR estimating unit 25, generates transmission power control information TPCC at the TPCC generating unit 26, and transmits the transmission power control information TPCC via the F-DPCH as first transmission power control information TPCC at relatively long periodic intervals (transmission period of the present mobile station). Also, in a case where packet transmission is conducted, the transmission power control information is transmitted via the HS-SCCH as second transmission power control information TPCC at a shorter periodic cycle. In this embodiment, transmission power control may be realized without having to transmit the pilot signal on a continual basis, and thereby, the power consumption rate for transmitting the pilot signal may be reduced. Also, in a case where data are transmitted via the HS-PDSCH, transmission power control may be conducted through transmission of an ACK/NACK signal before the transmission period of the first transmission power control information TPCC based on the transmission power control information TPCC that is previously transmitted via the HS-SCCH. Thereby, transmission power may be suitably controlled to quickly respond to the transmission quality such as the SIR of the wireless propagation path.

[0061] In a preferred embodiment, a predetermined number of pilot signals of a predetermined length are transmitted at a transmission period that is shorter than the transmission period of the first transmission power control information TPCC. When packet data are transmitted, it is likely that more data to be transmitted remain, and thereby, according to the present embodiment, preparation may be made for the transmission of the next data transmission in accordance with the transmission schedule.

[0062] Also, it is noted that the pilot transmission other than that in conjunction with the HS-SCCH transmission may be arranged to be conducted at a transmission period that is shorter than the transmission period of the first transmission power control information TPCC via the F-DPCH. When pilot signals are received and processed to realize SIR estimation, the estimation accuracy may be improved by increasing the number of pilot signals although increasing the pilot signal transmission leads to an increase in the power consumption for transmitting the pilot signal. Accordingly, in one embodiment, the transmission period for the first transmission power control information may be arranged to be relatively long to reduce power consumption, and the transmission period for transmitting the pilot signal may be adjusted to a shorter period in order to avoid degradation of the estimation accuracy.

[0063] In another embodiment, the first transmission power control information TPCC1 transmitted via the F-DPCH, and the second transmission power control information TPCC2 transmitted via the HS-SCCH may be arranged to represent different transmission power control levels. In such a case, the second transmission power

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control information TPCC2 is arranged to be greater than the first transmission power control information TPCC1 (TPCC1 < TPCC2). According to the present embodiment, in transmitting the ACK/NACK signal, for example, the second transmission power control information TPCC2 that is previously received via the HS-SCCH may be used to swiftly control the transmission power to a desired level.

[0064] It is noted that in the illustrated example of FIG. 6, the leftmost TPC bit in the HS-SCCH is generated based on the most recently received pilot signal before this TPC bit (i.e., the second pilot signal from the left in FIG.6). When a mobile station receives the third (from the left) pilot signal, the mobile station may generate the second (from the left) TPC bit in the HS-SCCH based on the third pilot signal, and thereby, accurate transmission power control may be conducted upon transmitting the first ACK signal.

[0065] Also, in the illustrated example of FIG.6, there is an interval between the second TPC bit and the third TPC bit in the HS-SCCH; however, since a predetermined number of the pilot signals at predetermined lengths are arranged to be transmitted in conjunction with the HS-SCCH transmission in the present embodiment, the TPC bit may be generated based on a pilot signal being transmitted at a shorter period compared to the transmission period of the first transmission power control information (e.g., the third TPC bit in the HS-SCCH is generated based on the sixth pilot signal). It is noted that in a preferred embodiment, the base station may recognize the transmission timing of the first transmission power control information TPCC1 addressed to plural mobile stations, and define and store a time period T that is shorter than the transmission period of the first transmission power control information TPCC1 for the respective mobile stations so that a HS-SCCH and/or a HS-PDSCH addressed to a mobile station may be transmitted to this mobile station before the time period T elapses from the transmission timing of the first transmission power control information TPCC1.

[0066] It is noted that the channel HS-PDSCH corresponds to a shared channel, and thereby, data addressed to plural mobile stations may be transmitted via this channel. According to the present embodiment, the HS-PDSCH is arranged to prioritize data transmission to a mobile station at which the elapsed time from a transmission timing of the first transmission power control information TPCC1 is not so long. According to such an arrangement, transmission power control may be effectively realized without including transmission power control information in the HS-SCCH. In one embodiment, the transmission power control information may be omitted for a first HS-SCCH (e. g. , a HS-SCCH of which transmission timing interval with respect to a previous HS-SCCH is longer than the transmission period of the first transmission power control information TPCC1), and the transmission power control information may be included in a next HS-SCCH of which the transmission timing interval with respect to a previous HS-SCCH is shorter than the transmission period of the first transmission power control information TPCC1.

[0067] In this embodiment, the transmission period of the pilot signal for a mobile station is arranged to be shorter in response to receiving a first HS-SCH, and accordingly, transmission power control may be conducted at shorter intervals. Also, it is noted that in FIG.6, some of the pilot signals are transmitted in conjunction with the transmission timing of the ACK/NACK signals. By transmitting the ACK signal, the NACK signal, and the pilot signal in sync with the transmission of an uplink signal, transmission efficiency may be realized. Arranging the transmission timing of the pilot signal transmitted in conjunction with the HS-SCCH to be in accordance with the transmission timing of the pilot signal may be one way of improving the transmission efficiency.

[0068] It is noted that application of the present invention is not limited to the W-CDMA scheme or the OFDM scheme; rather, the present invention may be equally applied to wireless communication apparatuses and mobile wireless communication systems using other various wireless communication schemes.

[0069] Further, the present invention is not limited to the specific embodiments described above, and variations and modifications may be made without departing from the scope of the present invention.

Claims

1. A mobile wireless communication system that includes a wireless communication apparatus and a counterpart wireless communication apparatus, and is configured to establish wireless communication between the wireless communication apparatus and the counterpart wireless communication apparatus by multiplexing a plurality of channels including at least a traffic channel for transmitting a packet, a control channel for transmitting control information for receiving the packet, and a channel for transmitting information including transmission power control information, the system being **characterized in that**:

   the wireless communication apparatus includes a transmission unit that transmits the transmission control information to the counterpart wireless communication apparatus via the channel for transmitting information including transmission power control information at intervals of a prescribed period that is longer than a length of the packet, and transmits the transmission power control information via the control channel when the packet is being transmitted via the traffic channel.

2. The mobile wireless communication system as

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claimed in claim 1 wherein:

the counterpart wireless communication apparatus includes a transmission unit that transmits a pilot signal right before receiving the transmission power control information transmitted from the wireless communication apparatus via the channel for transmitting information including transmission power control information and right after receiving the transmission power control information transmitted from the wireless communication apparatus via the control channel.

3. The mobile wireless communication system as claimed in claim 2, wherein:

the transmission power control information transmitted from the wireless communication apparatus to the counterpart wireless communication apparatus includes first transmission power control information that is transmitted via the channel for transmitting information including transmission power control information and second transmission power control information that is transmitted via the control channel; and
the transmission unit of the counterpart wireless communication apparatus transmits the pilot signal at periodic intervals shorter than a transmission period at which the first transmission power control information is transmitted.

4. The mobile wireless communication system as claimed in claim 1, wherein
the transmission power control information transmitted from the wireless communication apparatus to the counterpart wireless communication apparatus includes first transmission power control information that is transmitted via the channel for transmitting information including transmission power control information and second transmission power control information that is transmitted via the control channel; and
a transmission power control level represented by the second transmission power control information is arranged to be greater than or equal to a transmission power control level represented by the first transmission power control information.

5. A wireless communication apparatus that is configured to transmit data within a mobile wireless communication system that realizes data transmission via a shared channel, the apparatus being **characterized by** comprising:

a transmission unit that is configured to transmit to a mobile station first transmission power control information at intervals of a prescribed period, and transmit control information for receiving the data including second transmission power control information when transmitting the data to the mobile station.

6. The wireless communication apparatus as claimed in claim 5, wherein a transmission power control level represented by the second transmission power control information that is included in the control information is arranged to be greater than or equal to a transmission power control level represented by the first transmission power control information that is transmitted at intervals of the prescribed period.

7. A wireless communication apparatus that is configured to receive data within a mobile wireless communication system that realizes data transmission via a shared channel, the apparatus being **characterized by** comprising:

a transmission unit that is configured to transmit a pilot signal in conjunction with receiving control information for receiving the data.

8. The wireless communication apparatus as claimed in claim 7 wherein:

the transmission unit is further configured to transmit the pilot signal at intervals of a prescribed period; and
the transmission of the pilot signal in conjunction with the reception of the control information is conducted at periodic intervals shorter than the prescribed period.

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TESLA, INC.

FIG.1

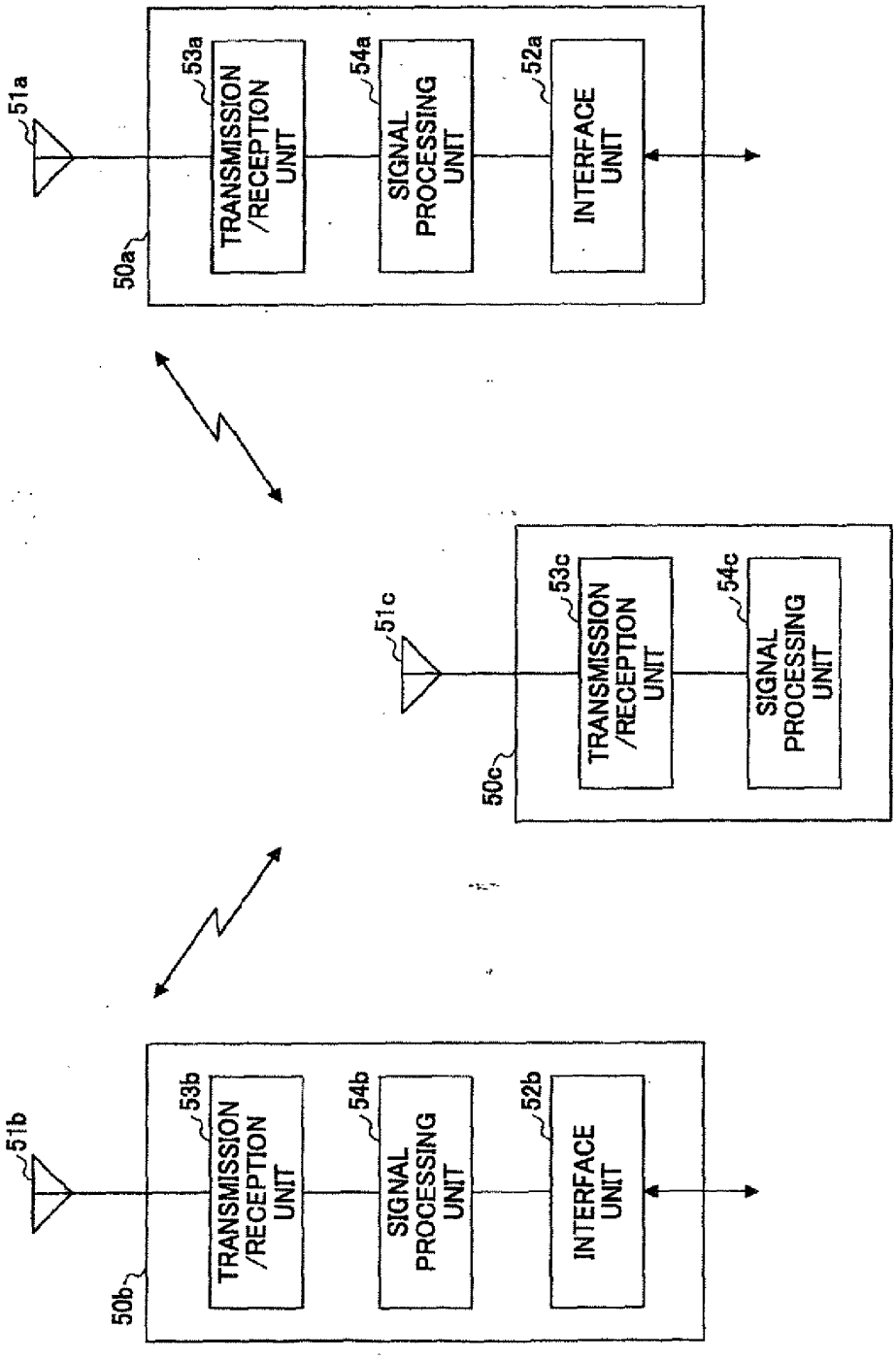

51a
53a
TRANSMISSION /RECEPTION UNIT
54a
SIGNAL PROCESSING UNIT
52a
INTERFACE UNIT
50a
51c
53c
TRANSMISSION /RECEPTION UNIT
54c
SIGNAL PROCESSING UNIT
50c
51b
53b
TRANSMISSION /RECEPTION UNIT
54b
SIGNAL PROCESSING UNIT
52b
INTERFACE UNIT
50b

FIG.2

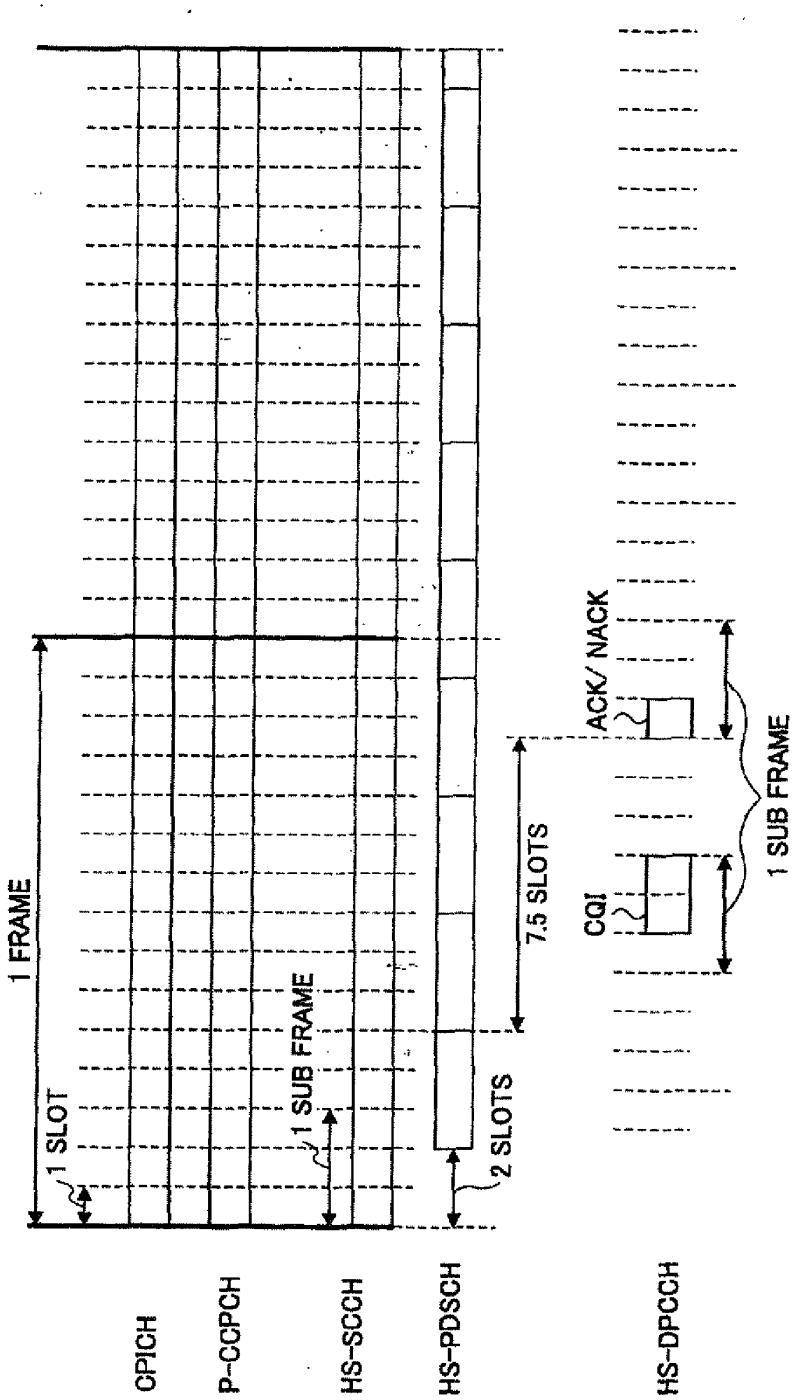

1 FRAME
1 SLOT
1 SUB FRAME
2 SLOTS
7.5 SLOTS
ACK/ NACK
CQI
1 SUB FRAME
CPICH
P-CCPCH
HS-SCCH
HS-PDSCH
HS-DPCCH

FIG.3

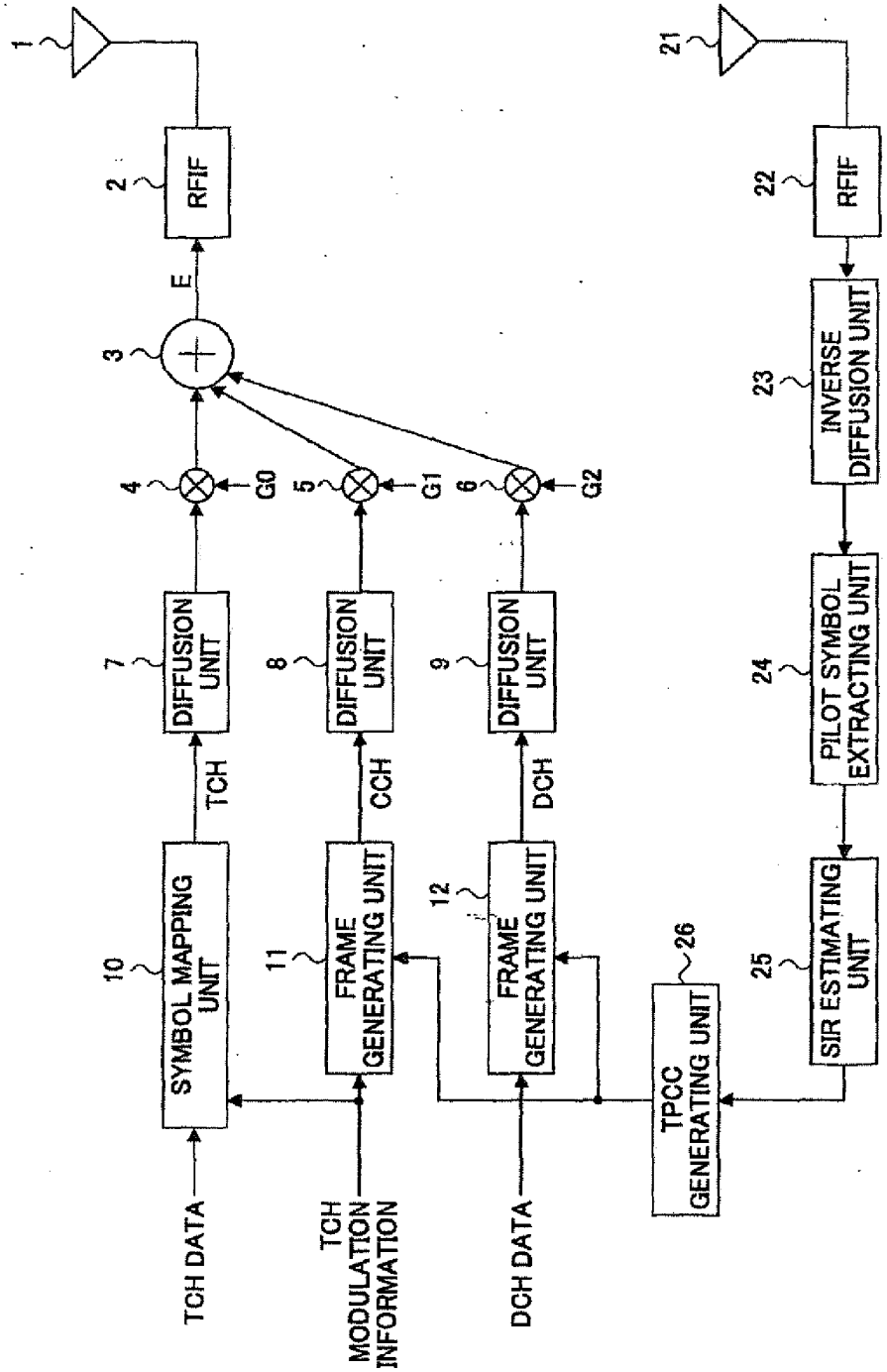

1
2
RFIF
E
3
4
G0
5
G1
6
G2
7
DIFFUSION UNIT
8
DIFFUSION UNIT
9
DIFFUSION UNIT
TCH
CCH
DCH
10
SYMBOL MAPPING UNIT
11
FRAME GENERATING UNIT
12
FRAME GENERATING UNIT
TCH DATA
TCH MODULATION INFORMATION
DCH DATA
26
TPCC GENERATING UNIT
21
22
RFIF
23
INVERSE DIFFUSION UNIT
24
PILOT SYMBOL EXTRACTING UNIT
25
SIR ESTIMATING UNIT

FIG.4

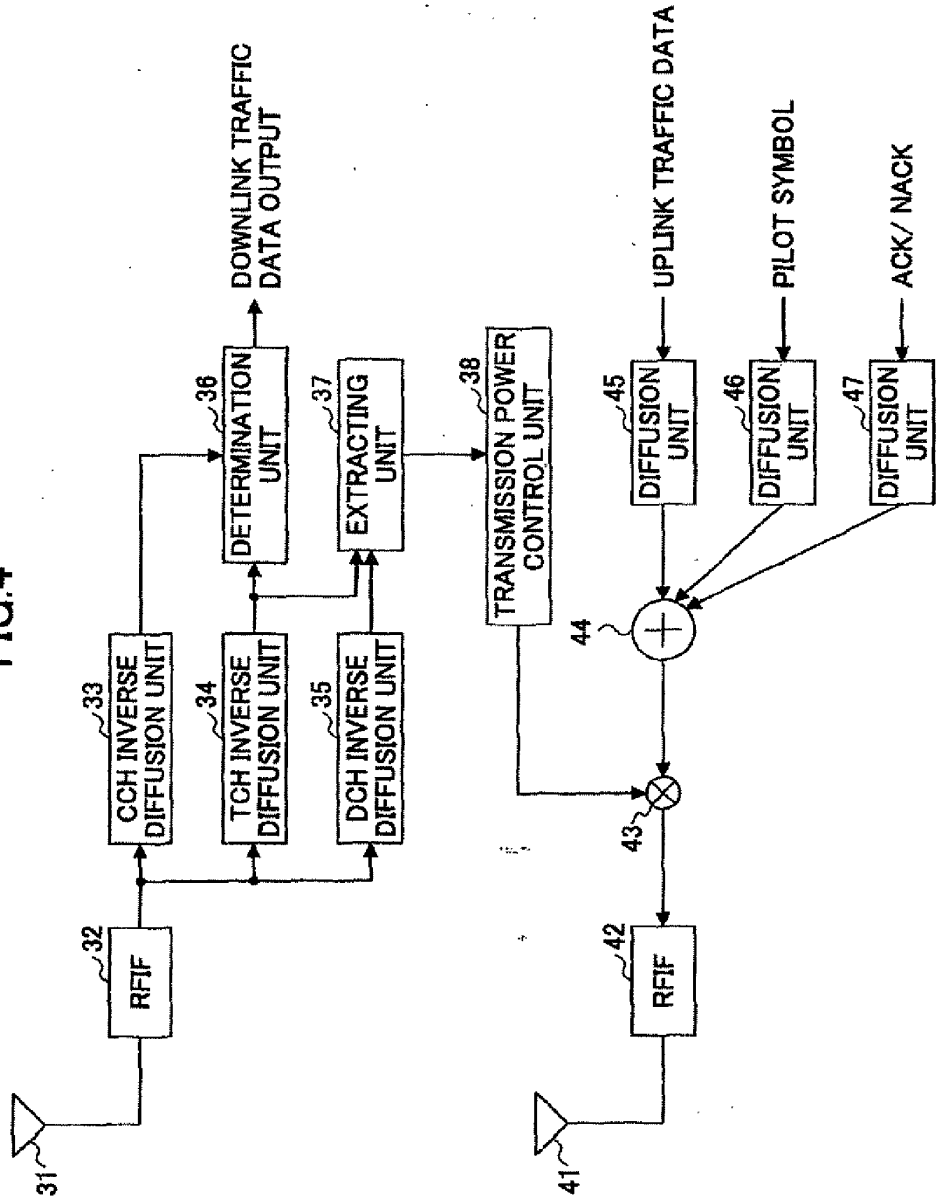

DOWNLINK TRAFFIC DATA OUTPUT
UPLINK TRAFFIC DATA
PILOT SYMBOL
ACK/ NACK
CCH INVERSE DIFFUSION UNIT
TCH INVERSE DIFFUSION UNIT
DCH INVERSE DIFFUSION UNIT
DETERMINATION UNIT
EXTRACTING UNIT
TRANSMISSION POWER CONTROL UNIT
DIFFUSION UNIT
DIFFUSION UNIT
DIFFUSION UNIT
RFIF
RFIF
31
32
33
34
35
36
37
38
41
42
43
44
45
46
47

FIG.5

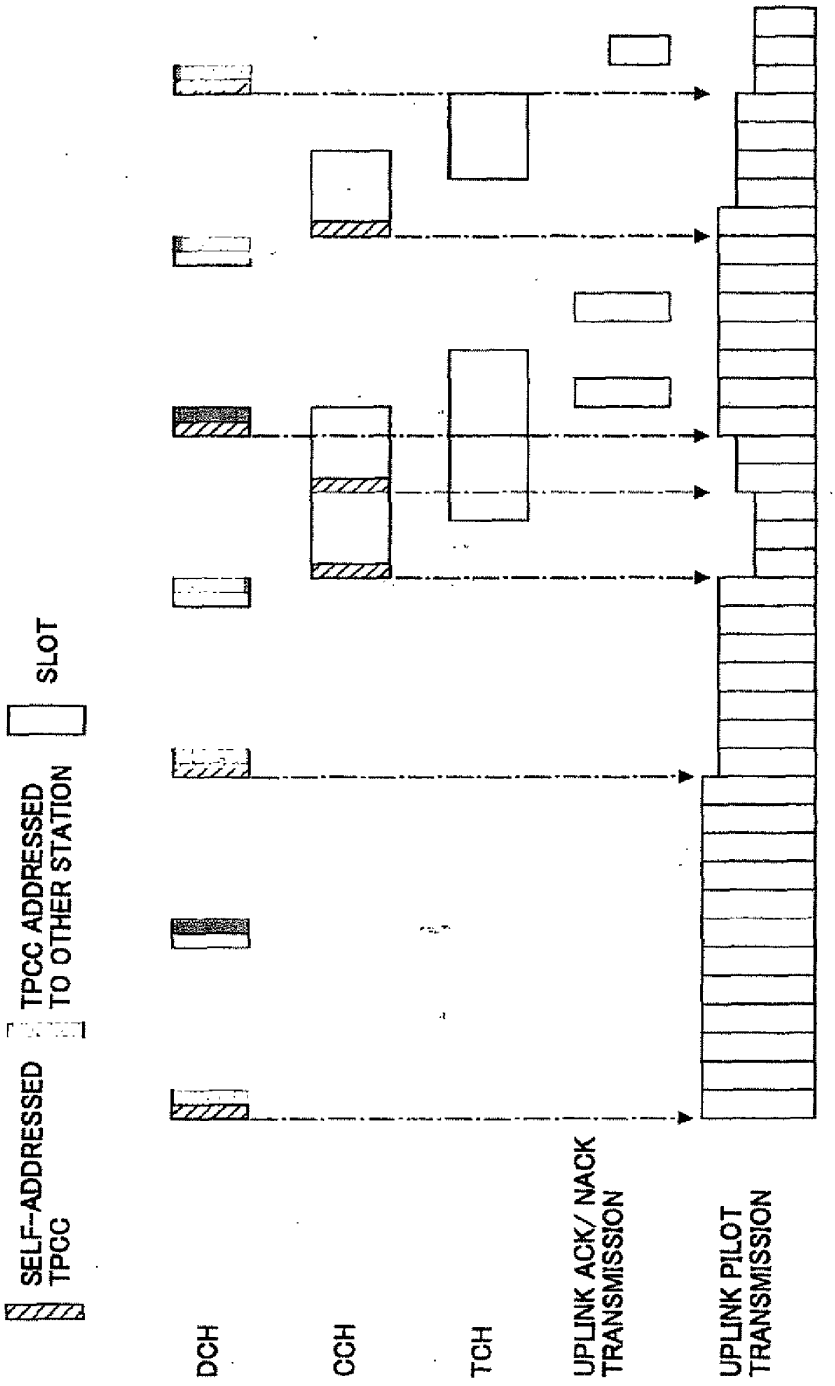
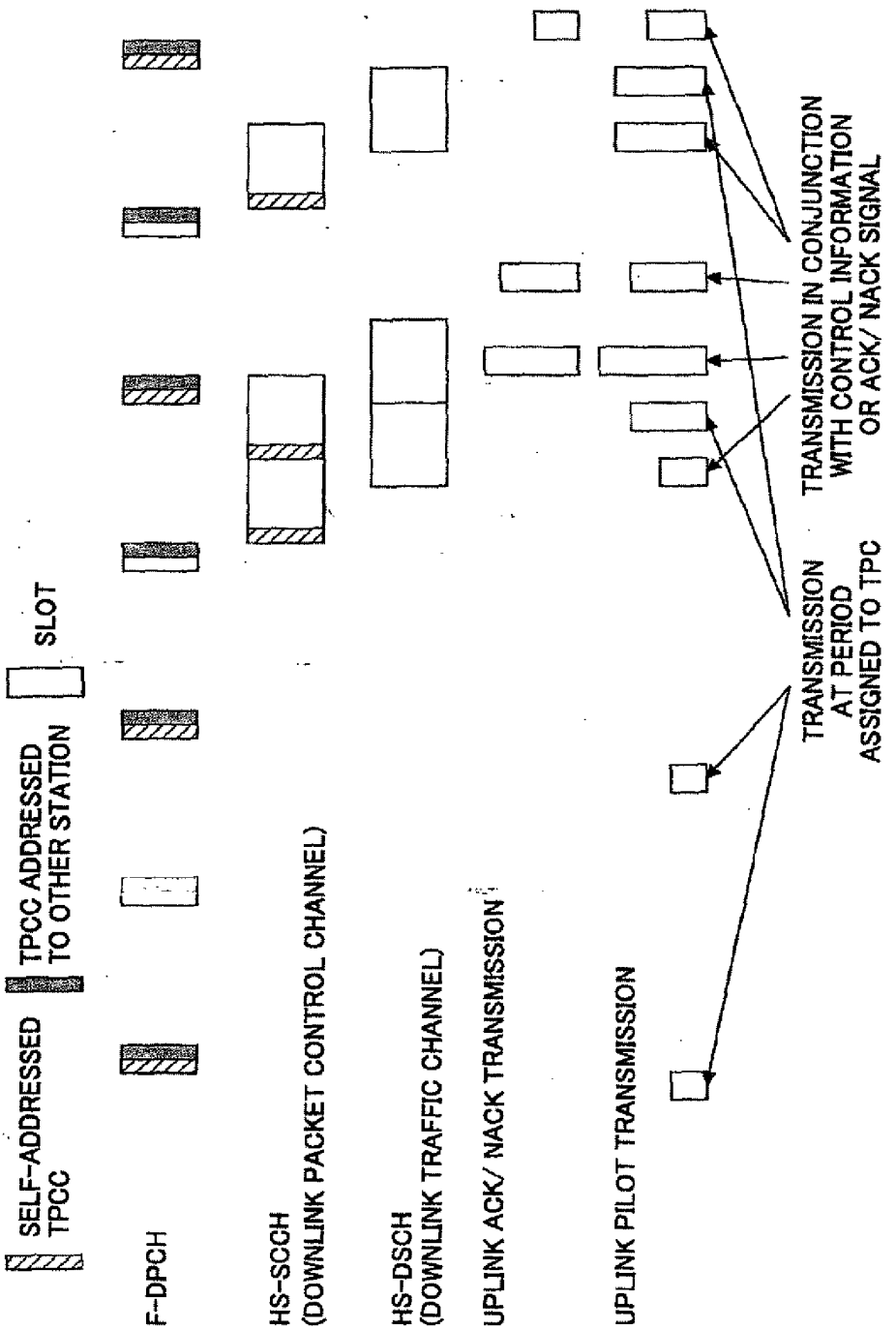

SLOT
TPCC ADDRESSED TO OTHER STATION
SELF-ADDRESSED TPCC
DCH
CCH
TCH
UPLINK ACK/ NACK TRANSMISSION
UPLINK PILOT TRANSMISSION

FIG.6


SELF-ADDRESSED TPCC
TPCC ADDRESSED TO OTHER STATION
SLOT
F-DPCH
HS-SCCH (DOWNLINK PACKET CONTROL CHANNEL)
HS-DSCH (DOWNLINK TRAFFIC CHANNEL)
UPLINK ACK/ NACK TRANSMISSION
UPLINK PILOT TRANSMISSION
TRANSMISSION AT PERIOD ASSIGNED TO TPC
TRANSMISSION IN CONJUNCTION WITH CONTROL INFORMATION OR ACK/ NACK SIGNAL

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 25 2610

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 6 611 508 B1 (ABE MASAMI) 26 August 2003 (2003-08-26) * abstract * * column 2, line 54 - column 6, line 5 * * claim 1 * * figures 1-4 *	5,6 1-4,7,8	H04B7/005
X	EP 1 351 411 A (LUCENT TECHNOLOGIES INC) 8 October 2003 (2003-10-08) * abstract * * paragraphs [0007], [0012] * * claim 1 * * figure 2 *	7,8	
A	EP 1 206 047 A (SAMSUNG ELECTRONICS CO., LTD) 15 May 2002 (2002-05-15) * abstract * * paragraphs [0134] - [0137] * * figure 16 *	1-8	
			TECHNICAL FIELDS SEARCHED (IPC) H04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 March 2006	Helms, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

Ex.1006 / Page 244 of 823
TESLA, INC.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 25 2610

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-03-2006

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6611508 B1	26-08-2003	JP 3307573 B2	24-07-2002
		JP 11145901 A	28-05-1999
EP 1351411 A	08-10-2003	DE 60300227 D1	27-01-2005
		DE 60300227 T2	15-12-2005
		JP 2003318821 A	07-11-2003
		US 2004203980 A1	14-10-2004
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		JP 2004514320 T	13-05-2004
		WO 0239623 A1	16-05-2002
		US 2002115464 A1	22-08-2002

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

Ex.1006 / Page 245 of 823
TESLA, INC.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/064483

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04Q7/32
ADD. H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04Q H04B H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 681 780 A (FUJITSU LTD [JP]) 19 July 2006 (2006-07-19)	1-4, 6-12, 14-17
Y	paragraph [0003] - paragraph [0012] paragraph [0016] - paragraph [0025] paragraphs [0030], [0031] paragraph [0039] - paragraph [0041] paragraph [0047] - paragraph [0060] figures 2-4,6	5,13
Y	US 2006/093026 A1 (MONTOJO JUAN [US] ET AL) 4 May 2006 (2006-05-04) paragraphs [0038], [0042], [0043] paragraph [0047] - paragraph [0049] paragraph [0055] - paragraph [0078] paragraphs [0095], [0096] paragraphs [0099], [0100] figures 2,5,6,8-10	5,13

-/--

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 May 2008	02/06/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bösch, Michael

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/064483

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 102 01 270 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 8 August 2002 (2002-08-08) paragraph [0007] - paragraph [0012] paragraphs [0017], [0019], [0023] paragraphs [0024], [0031] paragraph [0043] - paragraph [0045] paragraph [0053] - paragraph [0057] paragraph [0068] - paragraph [0071] paragraphs [0075], [0076] paragraph [0080] - paragraph [0082] paragraph [0084] - paragraph [0090] figures 1,3-7	1-17
A	EP 1 615 384 A (QUALCOMM INC [US]) 11 January 2006 (2006-01-11) paragraph [0012] - paragraph [0014] paragraph [0065] - paragraph [0089] paragraph [0100] - paragraph [0113] paragraph [0123] - paragraph [0125] paragraphs [0145], [0176], [0253] paragraphs [0308], [0309] paragraph [0316] - paragraph [0320] paragraph [0375] - paragraph [0381] paragraph [0423] - paragraph [0426] paragraph [0458] - paragraph [0464] figures 3A,3B,4	1-17

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/064483

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1681780 A	19-07-2006	CN 1805307 A	19-07-2006
		JP 2006197318 A	27-07-2006
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US 2006093026 A1	04-05-2006	NONE	
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		KR 20020061529 A	24-07-2002
		US 2002196766 A1	26-12-2002
EP 1615384 A	11-01-2006	EP 1619817 A2	25-01-2006

Electronic Acknowledgement Receipt

EFS ID:	12552347
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9010-99460-US
Receipt Date:	16-APR-2012
Filing Date:	05-JUL-2011
Time Stamp:	17:07:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	99460_IDS_Transmittal.pdf	119732 69d53c42c6a431215df4d56f10e37ae77c8b c359	no	2
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	99460_IDS_Form_04172012.pdf	613551 c3410bfc23f516a8808c9713173224af5a7892a7	no	6
Warnings:					
Information:					
3	Foreign Reference	DE10201270.pdf	1259492 c97c9af0ef20af16e29d225fa93f5164743e63f4	no	22
Warnings:					
Information:					
4	Foreign Reference	EP1467582.pdf	813379 9c4886edb72366d5dd97b856649046e5823931e7	no	24
Warnings:					
Information:					
5	Foreign Reference	EP1615384.pdf	3416640 8fdda84528d62582d189590a15a636677add6d00	no	98
Warnings:					
Information:					
6	Foreign Reference	EP1681780.pdf	727224 b5a42e7b6da801c8e0a5377cb94595faf5fa2842	no	19
Warnings:					
Information:					
7	Non Patent Literature	NPL1_04172012.pdf	233015 66eec22f063af8be2f4c3039537e6234b00f0ea4	no	6
Warnings:					
Information:					
8	Non Patent Literature	NPL2_04172012.pdf	295745 83736c0763bfa7f80bd9b066defe20d6ada10416	no	13
Warnings:					
Information:					
9	Non Patent Literature	NPL3_04172012.pdf	321220 91c82a619ddf53236c927b176ccbb347e4f4a22b	no	13
Warnings:					
Information:					
10	Non Patent Literature	NPL4_04172012.pdf	333670 f5bea271009f2d12a82030482b4e9998b1438edd	no	13
Warnings:					
Information:					

11	Non Patent Literature	NPL5_04172012.pdf	1338909 cd66b0c8a1f87ad4aa57e10794291355b1064418	no	42
Warnings:					
Information:					
12	Non Patent Literature	NPL6_04172012.pdf	1065030 faad24ea260456e7d9aebb52f645b3b9a60a8791	no	45
Warnings:					
Information:					
13	Non Patent Literature	NPL7_04172012.pdf	323981 5f20fe03be78cf01c120e79bfcedefcbecae9443	no	9
Warnings:					
Information:					
14	Non Patent Literature	NPL8_04172012.pdf	227134 5bc4d868804a36f086b34eaa587576bd3b206844	no	7
Warnings:					
Information:					
15	Non Patent Literature	NPL9_04172012.pdf	65694 4f0343f2e24450da797b0703cbb0540c729432e4	no	3
Warnings:					
Information:					
		Total Files Size (in bytes):	11154416		

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

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

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

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

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.	13/176,298
Filed:	July 5, 2011
First Named Inventor:	Paul Howard
Title:	**FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM**
Art Unit:	2473
Examiner:	Not Yet Assigned
Attorney Docket:	9010-99460-US
Customer No.:	22242

Confirmation No. 4342

CERTIFICATE OF EFS-WEB TRANSMISSION

I hereby certify that this IDS Transmittal is being transmitted via the United States Patent and Trademark Office (USPTO) electronic filing system (EFS-Web) to the USPTO on April 16, 2012.

Helen Donegan, Legal Assistant
to Steven Parmelee
Registration No. 28,790

Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313-1450

INFORMATION DISCLOSURE STATEMENT TRANSMITTAL

Sir:

Pursuant to the duty of disclosure under 37 C.F.R. § 1.56, and in accordance with MPEP § 601 and 37 C.F.R. §§ 1.97 and 1.98, Applicants and the undersigned attorney bring the information listed on Form PTO/SB/08a, filed concurrently herewith, to the attention of the Examiner.

Pursuant to 37 C.F.R. § 1.97(h), the filing of this Information Disclosure Statement shall not be construed to be an admission that the information cited in this statement is, or is considered to be, prior art or is material to patentability as defined in 37 C.F.R. § 1.56(b).

The Commissioner is hereby authorized to charge any additional fees which may be required with respect to this communication, or credit any overpayment, to Deposit Account No. 06-1135.

Respectfully submitted,

FITCH, EVEN, TABIN & FLANNERY

Dated: April 16, 2012

Steven G. Parmelee
Registration No. 28,790
sgparm@fitcheven.com

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Chicago, Illinois 606033406
Telephone (312) 577-7000
Facsimile (312) 577-7007

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.	13/176,298
Filed:	July 5, 2011
First Named Inventor:	Paul Howard
Title:	**FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM**
Art Unit:	2473
Examiner:	Not Yet Assigned
Attorney Docket:	9010-99460-US
Customer No.:	22242

Confirmation No. 4342

CERTIFICATE OF EFS-WEB TRANSMISSION

I hereby certify that this Preliminary Amendment is being transmitted via the United States Patent and Trademark Office (USPTO) electronic filing system (EFS-Web) to the USPTO on April 19, 2012.

Helen Donegan, Legal Assistant
to Steven Parmelee
Registration No. 28,790

PRELIMINARY AMENDMENT

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

Dear Sir:

Applicants respectfully submit the following preliminary amendment.

Amendments to the Specification are reflected on Page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims which begins on Page 3 of this paper.

Remarks are reflected beginning on Page 9.

AMENDMENTS TO THE SPECIFICATION

Please insert on page 1, immediately after the title and preceding "Background of the Invention," the following paragraph:

Related Applications

[0001] This application is a continuation of U.S. Patent Application No. 11/646,692, filed December 27, 2006, now U.S. Patent No. 8,009,639 which issued on August 30, 2011. The content of this document is incorporated herein in its entirety.

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claims 1-24 (Cancelled)

25. (New) A method of determining a channel condition between a base station and a mobile terminal in a wireless communications network, said mobile terminal arranged to transmit data to the base station on a shared uplink channel, access to the shared uplink channel being granted to the mobile terminal by a controller, the method comprising:

allocating by the controller uplink resources for the transmission of a reference signal from the mobile terminal;

transmitting the reference signal from the mobile terminal to the base station on the allocated uplink resources;

receiving the reference signal at the base station; and

determining from the reference signal a channel condition of the channel between the mobile terminal and the base station;

wherein the uplink resources allocated for the transmission of the reference signal are separate from the shared uplink channel allocated to the mobile terminal such that the mobile terminal is operable to transmit the reference signal independently of access granted to the mobile terminal by the controller to the shared uplink channel.

26. (New) A method according to claim 25, comprising

allocating a downlink channel for the base station to transmit a control signal in response to the reference signal; and

adjusting a transmission parameter of the mobile terminal on the basis of the control signal.

27. (New) A method according to claim 26, wherein the transmission parameter comprises power.

28. (New) A method according to claim 26, wherein the control signal is based upon at least one factor from the group consisting of:

path loss computed based upon a received power of the reference signal;

time of arrival of the reference signal; and

channel impulse response in response to the reference signal.

29. (New) A method according to claim 26, wherein allocating the downlink channel for the base station to transmit the control signal comprises allowing another downlink signal, separated in the code domain from the control signal, to share the downlink channel with the control signal.

30. (New) A method according to claim 26, wherein allocating the uplink resource for the transmission of the reference signal comprises allocating a first uplink time slot within a frame, the reference signal being transmitted during the first uplink time slot.

31. (New) A method according to claim 30, wherein the wireless communications network comprises a plurality of other mobile terminals and first

uplink time slots of at least some successive frames are allocated to different mobile terminals of the plurality of other mobile terminals for transmission of respective different reference signals.

32. (New) A method according to claim 31, wherein allocating the downlink channel for the transmission of the control signal comprises allocating a second downlink time slot within the frame, the control signal being transmitted during the second downlink time slot.

33. (New) A method according to claim 32 wherein the second downlink time slot of successive frames is used for transmitting the control signal to at least some of the plurality of other mobile terminals.

34. (New) A method according to claim 31, further comprising:

determining to which mobile terminal of the plurality of other mobile terminals the first uplink time slot should be allocated based upon at least one factor from the group consisting of:

expected volume of data transfer expected;

required data transfer rate;

frequency of short bursts of data transfer;

total number of mobile terminals connected to the network;

time since last data transfer; and

mobile terminal power saving requirements.

35. (New) A controller for controlling transmission of data between a mobile terminal and a base station in a wireless communication network, the controller being operable to:

grant the mobile terminal access to a shared uplink channel for transmitting data to the base station; and

allocate the mobile terminal uplink resource for the transmission of a reference signal to the base station;

wherein the uplink resources allocated for the transmission of the reference signal are separate from the shared uplink channel allocated to the mobile terminal such that the mobile terminal is operable to transmit the reference signal independently of access granted to the mobile terminal by the controller to the shared uplink channel.

36. (New) A controller according to claim 35, wherein the controller is operable to allocate a downlink channel for the base station to transmit a control signal to the mobile terminal in response to the reference signal, and the mobile terminal is thereby able to adjust a transmission parameter on the basis of the control signal.

37. (New) A controller according to claim 36, wherein the transmission parameter comprises power.

38. (New) A controller according to of claim 36, wherein the control signal is based upon at least one factor from the group consisting of:

path loss computed based upon a received power of the reference signal;

time of arrival of the reference signal; and

channel impulse response in response to the reference signal.

39. (New) A controller according to claim 36, wherein the controller is arranged to allocate the downlink channel for the base station to transmit the control signal by allowing another downlink signal, separated in the code domain from the control signal, to share the downlink channel with the control signal.

40. (New) A controller according to claim 36, wherein the controller is operable to allocate the uplink resource for the transmission of the reference signal by allocating a first uplink time slot within a frame, the reference signal being transmitted during the first uplink time slot.

41. (New) A controller according to claim 40, wherein the controller is operable to allocate first uplink time slots of at least some successive frames to different mobile terminals of a plurality of other mobile terminals for transmission of respective different reference signals.

42. (New) A controller according to claim 39, wherein the controller is arranged to allocate the downlink channel for the transmission of the control signal by allocating a second downlink time slot within the frame, the control signal being transmitted during the second downlink time slot.

43. (New) A controller according to claim 42, wherein the controller is arranged to allocate the second downlink time slot of successive frames for transmitting the control signal to at least some of the plurality of other mobile terminals.

44. (New) A controller according to claim 41, wherein the controller is arranged to determine to which mobile terminal of the plurality of other mobile

terminals the first uplink time slot should be allocated based upon at least one factor from the group consisting of:

expected volume of data transfer expected;

required data transfer rate;

frequency of short bursts of data transfer;

total number of mobile terminals connected to the network;

time since last data transfer; and

mobile terminal power saving requirements.

REMARKS

We submit herewith this Preliminary Amendment and note that all amendments have been made in accordance with 37 CFR §1.121(b)-(c). The specification has been amended to add the section entitled "Cross-Reference To Related Application" which makes reference to the priority application as claimed by Applicants and Substitute Claims have been added.

We respectfully request entry of the Preliminary Amendment and that the proposed changes be considered when the application is examined on the merits.

Respectfully submitted,

FITCH, EVEN, TABIN & FLANNERY

Dated: April 19, 2012

Steven G. Parmelee
Registration Nos. 28,790

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Electronic Acknowledgement Receipt

EFS ID:	12582885
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Steven Glen Parmelee/Helen Donegan
Filer Authorized By:	Steven Glen Parmelee
Attorney Docket Number:	9010-99460-US
Receipt Date:	19-APR-2012
Filing Date:	05-JUL-2011
Time Stamp:	15:46:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		99460_Preliminary_Amendment.pdf	547929 e9b30bd1f9b77f9e6c86985585e55a15606f6d3a	yes	9

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Preliminary Amendment	1	1
	Specification	2	2
	Claims	3	8
	Applicant Arguments/Remarks Made in an Amendment	9	9
Warnings:			
Information:			
	Total Files Size (in bytes):	547929	

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

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

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

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

PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/176,298	Filing Date 07/05/2011	☐ To be Mailed

APPLICATION AS FILED – PART I

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

APPLICATION AS AMENDED – PART II

AMENDMENT **04/19/2012**

	(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $ =		OR	X $60=	0
Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $ =		OR	X $250=	0
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

AMENDMENT

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DAVID SASFAI/

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

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PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/176,298	Filing Date 07/05/2011	☐ To be Mailed

APPLICATION AS FILED – PART I

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

APPLICATION AS AMENDED – PART II

AMENDMENT **04/19/2012**

	(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 22	Minus	** 20	= 2	X $ =		OR	X $60=	120
Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $ =		OR	X $250=	0
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**120**

AMENDMENT

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DAVID SASFAI/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/176,298	Filing Date 07/05/2011	☐ To be Mailed

APPLICATION AS FILED – PART I

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

APPLICATION AS AMENDED – PART II

AMENDMENT **04/25/2012**

	(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 22	Minus	** 20	= 2	X $ =		OR	X $60=	120
Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X $ =		OR	X $250=	0
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**120**

AMENDMENT

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DAVID SASFAI/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
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PTO/SB/80 (11-08)
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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

[X] Practitioners associated with the Customer Number: **3624**

OR

[ ] Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

[X] The address associated with Customer Number: **3624**

OR

[ ] Firm or Individual Name					
Address					
City		State		Zip	
Country		Telephone		Email	

Assignee Name and Address:

Intellectual Ventures Holding 81 LLC
7251 W. Lake Mead Blvd.
Suite 300
Las Vegas, NV 89128

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	24 May 2012
Name	Jeremy Sanders	Telephone	
Title	Authorized Person for Intellectual Ventures Holding 81 LLC		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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

DECLARATION REGARDING AUTHORITY TO SIGN ON BEHALF OF A LEGAL ENTITY
(37 C.F.R. 3.73(b)(2)(i))

I, Jeremy Sanders (whose title is supplied below), hereby declare that I am authorized to sign on behalf of Intellectual Ventures Holding 81 LLC.

Jeremy Sanders, Authorized Person for Intellectual Ventures Holding 81 LLC

24 May 2012
[date]

PTO/SB/96 (07-09)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Intellectual Ventures Holding 81 LLC

Application No./Patent No.: 13/176,298 Filed/Issue Date: July 5, 2011

Titled: FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM

INTELLECTUAL VENTURES HOLDING 81 LLC , a LIMITED LIABILITY COMPANY

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

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;

2. ☐ an assignee of less than the entire right, title, and interest in (The extent (by percentage) of its ownership interest is _____ %); or

3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

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

OR

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

1. From: PAUL HOWARD To: IPWIRELESS, INC.

The document was recorded in the United States Patent and Trademark Office at
Reel 027937 , Frame 0788 , or for which a copy thereof is attached.

2. From: IPWIRELESS, INC. To: NORTHROP GRUMMAN INFORMATION TEC

The document was recorded in the United States Patent and Trademark Office at
Reel 027938 , Frame 0301 , or for which a copy thereof is attached.

3. From: NORTHROP GRUMMAN INFORMATION TEC To: IPWIRELESS, INC.

The document was recorded in the United States Patent and Trademark Office at
Reel 027938 , Frame 0464 , or for which a copy thereof is attached.

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

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

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

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

/Jeremy Sanders/ May 24, 2012

Signature Date

Jeremy Sanders Authorized Person IVH81LLC

Printed or Typed Name Title

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

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

Privacy Act Statement

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

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

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

STATEMENT UNDER 37 CFR 3.73(b) CONTINUED

Applicant/Patent Owner: Intellectual Ventures Holding 81 LLC

Application No./Patent No.: 13/176,298

Filed/Issue Date: July 5, 2011

Titled: FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM

4. **From:** IPWIRELESS, INC. **To:** WIRELESS TECHNOLOGY SOLUTIONS LLC

The document was recorded in the United States Patent and Trademark Office at Reel 027938 **, Frame** 0566

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EFS ID:	13285329
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Harry Vartanian
Filer Authorized By:	
Attorney Docket Number:	9010-99460-US
Receipt Date:	18-JUL-2012
Filing Date:	05-JUL-2011
Time Stamp:	20:53:47
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	IPW2_USCN191712_POA.PDF	911781 69cff9b09771e28471c033f443d31dfef1f4d8c3	no	1

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2	Assignee showing of ownership per 37 CFR 3.73(b).	IPW2_USCN191712_3_73b_Authorization.PDF	208010 fc97659ff2f6d1a5020cec38c4160d94c6cfec36	no	1
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3	Assignee showing of ownership per 37 CFR 3.73(b).	IPW2_USCN191712_3_73b_Statement.PDF	561616 e55b7355d9c8c1c9c390501de7be8f0f9dc6c654	no	2
Warnings:					
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4	Assignee showing of ownership per 37 CFR 3.73(b).	IPW2_USCN191712_3_73b_Continued.PDF	66666 870ab1693f40709cce5ec482e182d96a32072c2d	no	1
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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2472
	Examiner Name	Hassan Kizou
	Attorney Docket Number	IPW2-USCN191712

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2472
	Examiner Name	Hassan Kizou
	Attorney Docket Number	IPW2-USCN191712

	1	3RD GENERATION PARTNERSHIP PROJECT, "Technical Specification Group Radio Access Network; Radio Resource Control (RRC); Protocol Specification (Release 7)," 3GPP TS 25.331 V7.3.0, December 2006.	☐
	2	Non-Final Rejection issued by USPTO, dated May 14, 2009 for 11/646,692.	☐
	3	Final Rejection issued by USPTO, dated November 19, 2009 for 11/646,692.	☐
	4	Non-Final Rejection issued by USPTO, dated May 28, 2010 for 11/646,692.	☐
	5	Notice of Allowance issued by USPTO, dated February 2, 2011 for 11/646,692.	☐
	6	Notice of Allowance issued by USPTO, dated May 17, 2011 for 11/646,692.	☐

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	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2472
	Examiner Name	Hassan Kizou
	Attorney Docket Number	IPW2-USCN191712

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☒ None

SIGNATURE

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

Signature	/Harry Vartanian/	Date (YYYY-MM-DD)	2012-07-20
Name/Print	Harry Vartanian	Registration Number	56,787

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EFS ID:	13302386
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	22242
Filer:	Harry Vartanian
Filer Authorized By:	
Attorney Docket Number:	9010-99460-US
Receipt Date:	20-JUL-2012
Filing Date:	05-JUL-2011
Time Stamp:	16:16:47
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	WO_2006_063138.PDF	1493461 c7a9c81a612d052d9dc36c35103002f60191ae44	no	43

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2	Other Reference-Patent or Application Document	05_14_2009_Non_Final_Rejection.PDF	389006 da66dd7d338ca8ebcef053b311aeac1fbfbe1e13	no	14
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3	Other Reference-Patent or Application Document	11_19_2009_Final_Rejection.PDF	358030 2a9f35f338edc7ddc8a1ce91d266373b0df5b3b8	no	13
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4	Other Reference-Patent or Application Document	05_28_2010_NonFinal_Rejection.PDF	289908 4f2adec557a997ef2fa54954b282ea6878a209ba	no	11
Warnings:					
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5	Other Reference-Patent or Application Document	02_02_2011_NoticeofAllowance.PDF	249420 491e0eb3ade0d3ff44d4b2921544a6298674df57	no	4
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6	Other Reference-Patent or Application Document	5_17_2011_NoticeofAllowance.PDF	326120 a8e50e3a4beeabd71a4bd6d0cc1a36e599aac151	no	5
Warnings:					
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7	Non Patent Literature	25_331_V7_3_0.pdf	7052745 07e3d1d22eb5d6f32bab47036654b73f08bde738	no	1317
Warnings:					
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8	Information Disclosure Statement (IDS) Form (SB08)	20120720_IPW2_USCN191712_IDS.PDF	792900 8219cf0582936293f02368c0a0a64babb37797d3	no	4
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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 June 2006 (15.06.2006)

PCT

(10) International Publication Number
WO 2006/063138 A2

(51) International Patent Classification:
H04L 1/02 (2006.01)

(21) International Application Number:
PCT/US2005/044429

(22) International Filing Date:
7 December 2005 (07.12.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/007,570 7 December 2004 (07.12.2004) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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WO 2006/063138 A2

(54) Title: COOPERATIVE MIMO IN MULTICELL WIRELESS NETWORKS

(57) Abstract: A method and system for cooperative multiple-input multiple output (MIMO) transmission operations in a multicell wireless network. Under the method, antenna elements from two or more base stations are used to from an augmented MIMO antenna array that is used to transmit and receive MIMO transmissions to and from one or more terminals. The cooperative MIMO transmission scheme supports higher dimension space-time-frequency processing for increased capacity and system performance.

COOPERATIVE MIMO IN MULTICELL WIRELESS NETWORKS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of communications systems; more particularly, the present invention relates to techniques for performing MIMO operations in a multicell wireless network.

COOPERATIVE MIMO IN MULTICELL WIRELESS NETWORKS

BACKGROUND OF THE INVENTION

[0002] With high-speed wireless services increasingly in demand, there is a need for more throughput per bandwidth to accommodate more subscribers with higher data rates while retaining a guaranteed quality of service (QoS). In point-to-point communications, the achievable data rate between a transmitter and a receiver is constrained by the available bandwidth, propagation channel conditions, as well as the noise-plus-interference levels at the receiver. For wireless networks where a base-station communicates with multiple subscribers, the network capacity also depends on the way the spectral resource is partitioned and the channel conditions and noise-plus-interference levels of all subscribers. In current state-of-the-art, multiple-access protocols, *e.g.*, time-division multiple access (TDMA), frequency-division multiple-access (FDMA), code-division multiple-access (CDMA), are used to distribute the available spectrum among subscribers according to subscribers' data rate requirements. Other critical limiting factors, such as the channel fading conditions, interference levels, and QoS requirements, are ignored in general.

[0003] The fundamental phenomenon that makes reliable wireless transmission difficult to achieve is time-varying multipath fading. Increasing the quality or reducing the effective error rate in a multipath fading channel may be extremely difficult. For instance, consider the following comparison between a typical noise source in a non-multipath environment and multipath fading. In environments having additive white Gaussian noise (AWGN), it may require only 1- or 2-db higher signal-to-noise ratio (SNR) using typical modulation and coding schemes to reduce the effective bit error rate (BER) from 10^{-2} to 10^{-3}. Achieving the same reduction in a multipath fading environment, however, may require up to 10 db improvement in SNR. The necessary improvement in SRN may not be achieved by simply providing higher transmit power or additional bandwidth, as this is contrary to the requirements of next generation broadband wireless systems.

[0004] One set of techniques for reducing the effect of multipath fading is to employ a signal diversity scheme, wherein a combined signal is received via independently fading channels. Under a space diversity scheme, multiple antennas are

used to receive and/or send the signal. The antenna spacing must be such that the fading at each antenna is independent (coherence distance). Under a frequency diversity scheme, the signal is transmitted in several frequency bands (coherence BW). Under a time diversity scheme, the signal is transmitted in different time slots (coherence time). Channel coding plus interleaving is used to provide time diversity. Under a polarization diversity scheme, two antennas with different polarization are employed for reception and/or division.

[0005] Spatial diversity is commonly employed in modern wireless communications systems. To achieve spatial diversity, spatial processing with antenna arrays at the receiver and/or transmitter is performed. Among many schemes developed to date, multiple-input multiple-output (MIMO) and beamforming are the two most studied and have been proved to be effective in increase the capacity and performance of a wireless network, (see, *e.g.*, Ayman F. Naguib, Vahid Tarokh, Nambirajan Seshadri, A. Robert Calderbank, "A Space-Time Coding Modem for High-Data-Rate Wireless Communications", IEEE Journal on Selected Areas in Communications, vol. 16, no. 8, October 1998 pp. 1459–1478). In a block time-invariant environment, it can be shown that in a system equipped with Nt transmit antennas and Nr receive antennas, a well designed space-time coded (STC) systems can achieve a maximum diversity of Nr*Nt. Typical examples of STC include space-time trellis codes (STTC) (see, *e.g.*, V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space-time codes for high data rate wireless communication: performance criterion and code construction", IEEE Trans. Inform. Theory, 44:744–765, March 1998) and space-time block codes from orthogonal design (STBC-OD) (see, *e.g.*, V. Tarokh, H. Jafarkhani, and A. R. Calderbank, "Space-time block codes from orthogonal designs", IEEE Trans. Inform. Theory, 45:1456–1467, July 1999.)

[0006] Since the capacity and performance of an MIMO system depends critically on its dimension (*i.e.*, Nt and Nr) and the correlation between antenna elements, larger size and more scattered antenna arrays are desirable. On the other hand, costs and physical constraints prohibit the use of excessive antenna arrays in practice.

SUMMARY OF THE INVENTION

[0007] A method and system is disclosed herein for cooperative multiple-input multiple output (MIMO) transmission operations in a multicell wireless network. Under one embodiment, antenna elements from two or more base stations are used to from an augmented MIMO antenna array that is used to transmit and receive MIMO transmissions to and from one or more terminals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present invention will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

[0009] Figure 1 depicts a multicell scenario where antenna elements from multiple base-stations are augmented to form a higher dimension MIMO transceiver array.

[0010] Figure 2 shows a generic channel matrix H used for modeling the capacity of MIMO systems.

[0011] Figure 3 shows the capacity increase of an MIMO system with respect to the number of transmitting antennas.

[0012] Figure 4a shows a cooperative MIMO architecture under which antenna arrays from two base stations are employed in a cooperative MIMO transmission scheme to transmit downlink signals to one terminal.

[0013] Figure 4b shows aspects of the cooperative MIMO architecture of Figure 4a employed for transmitting and processing uplink signals received by the augmented antenna array.

[0014] Figure 5 shows an extension to the cooperative MIMO architecture of Figure 4a, wherein beamforming is used to direct a MIMO transmission toward one terminal while performing spatial nulling towards another terminal.

[0015] Figure 6 shows a cooperative MIMO architecture under which two base-stations performing multiuser MIMO with two terminals simultaneously using joint encoding and decoding.

[0016] Figure 7a shows a block diagram of an MIMO OFDM encoder/transmitter.

[0017] Figure 7b shows the block diagram of an MIMO OFDM encoder/transmitter with beamforming.

[0018] Figure 8 shows a block diagram of an MIMO OFDM receiver/decoder.

[0019] Figure 9 shows a block diagram used to model a space-time coding transmission scheme.

[0020] Figure 10 shows an exemplary PSK-based space-time trellis code (STTC) encoder.

[0021] Figure 11 shows an exemplary QAM-based STTC encoder.

[0022] Figure 12 shows a block diagram used to model a space-time block coding (STBC) transmission scheme.

[0023] Figure 13a shows a block diagram modeling an STTC delay diversity scheme.

[0024] Figure 13b shows a block diagram modeling an STBC delay diversity scheme.

[0025] Figure 14 is a block diagram of an exemplary PSK-based STTC delay diversity encoder.

[0026] Figure 15 is a schematic diagram illustrating a cooperative MIMO architecture under which STC encoding operations are performed at a master encoder.

[0027] Figure 16 is a schematic diagram illustrating a cooperative MIMO architecture under which STC encoding operations are performed on respective instances of replicated data streams at multiple base stations.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0028] In accordance with aspects of the present invention, a method and apparatus to augment antenna elements from two or more base-stations/terminals to perform higher dimensional MIMO operations is disclosed. In one implementation, MIMO/joint space-time coding is employed across multiple base stations in a cellular environment, wherein the cooperative transmission of signals is performed at the modulation and coding level. This novel approach introduces additional diversities and capacities to existing network components with minimal additional costs. Because of the increase in the number of transmit antennas, the number of simultaneous users increases, leading to better spectrum efficiency.

[0029] In the following description, numerous details are set forth to provide a more thorough explanation of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

[0030] Some portions of the detailed descriptions which follow are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[0031] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description,

discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0032] The present invention also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[0033] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general-purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

[0034] A machine-readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (*e.g.*, a computer). For example, a machine-readable medium includes read only memory ("ROM"); random access memory ("RAM"); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (*e.g.*, carrier waves, infrared signals, digital signals, *etc.*); *etc.*

OVERVIEW

[0035] Figure 1 depicts three cells 100, 102, and 104 for a typical wireless network with multiple base stations BS1, BS2 and BS3 and terminals A, B, and C. Each of base stations BS1 and BS2 includes a 4-element circular antenna array, while terminal A has two antennas 1 and 2.

[0036] From a theoretical viewpoint, the capacity between a transmitter and a receiver for a MIMO transmission scheme is determined by the vector channel H, which is also referred to as the channel matrix. As illustrated in Figure 2, the channel matrix H includes M rows and N columns, wherein M is the number of receiver antennas (Rx) and N is the number of transmitter antennas (Tx). In the illustrated channel matrix H, each entry α_{ij} is the complex channel gain from the i-th transmit antenna to the j-th receive antenna.

[0037] The channel capacity for a Single-Input Single-Output (SISO) channel is,

$$C = \log_2(1+\rho) \text{ bits/sec/use} \qquad (1),$$

where ρ is the signal to noise ratio. The channel capacity for a MIMO channel is,

$$C = \log_2 \det\left[I + \frac{\rho}{N} HH^*\right] \qquad (2),$$

From above, the outage capacity can be shown to be,

$$C = \frac{1}{2} M \log_2(1+\sigma\{h\}^2 \rho) \qquad (3),$$

[0038] It is observed that under equation 3, the capacity increases linearly with the number of receive antennas when M is large. The channel capacity limit grows logarithmically when adding an antenna array at the receiver side (Single-Input Multiple-Output – SIMO). Meanwhile, the channel capacity limit grows as much as linearly with min(M,N), which is the maximum number of spatial eigenmodes, in the case of a MIMO

system. An illustration of a MIMO system capacity as a function of channel matrix dimension is shown in Figure 3.

[0039] Since the system capacity is dictated by the dimension (number of antennas) and the condition (correlation between antenna elements) of the channel, it is desirable to have large size antenna array with more scattered elements. However, there is a point of diminishing return, wherein the costs of adding antenna elements and corresponding processing complexity for a given base station exceeds the benefit of the incremental increase in system capacity. Furthermore, to obtain the added benefit of extra capacity, it may be necessary to add additional antenna elements to many or all base stations within a given wireless network.

[0040] Embodiments of the present invention take advantage of the benefit of having large size antenna arrays with more scattered elements without requiring additional antenna elements to be added to base stations. This is accomplished by augmenting the operations of antenna elements from two or more base stations to form a larger size antenna array. The augmented array performs "cooperative MIMO" transmission operations for one or more terminals. For example, Figure 1 shows an exemplary use of a cooperative MIMO transmission scheme, wherein the antenna elements for base stations BS1 and BS2 are augmented to cooperatively communicate via receive antennas 1 and 2 for terminal A.

[0041] Figure 4a depicts a block diagram of one embodiment of a downlink (from base stations to terminals) cooperative MIMO architecture 400. For illustrative purposes, the architecture shown in Figure 4a include two base stations 402 and 404 and a single terminal 406. It will be understood that an actual implementation of MIMO architecture 400 may include two or more base stations that transmit signals that are received by one or more terminals.

[0042] In the illustrated embodiment of Figure 4a, base station 402 has an antenna array including Nt_1 transmit antennas, while base station 404 has an antenna array including Nt_2 antennas and terminal 406 includes Nr antennas. In view of the foregoing MIMO definitions, the cooperative use of the base station antennas increases the MIMO dimension to $(Nt_1+Nt_2)*Nr$. This increase in dimension is accomplished

without requiring any additional antenna elements at the base stations, as well as the components use to drive the antennas.

[0043] According to aspects of various embodiments of the invention described herein, an information bit sequence corresponding to data to be transmitted to a subscriber (*e.g.*, terminal 406) may be space-time, space-frequency, or space-time-frequency coded, as depicted by a block 408 in Figure 4a. In some embodiments, space-time, space-frequency, or space-time-frequency codes may be augmented to support delay diversity, as described below. After appropriate encoding is performed in block 408, the coded data is then passed to the base stations, whereupon it is transmitted via applicable antenna elements at those base stations. The two or more base stations then perform joint MIMO transmissions (depicted as signals 410 and 412) towards the subscriber (*e.g.*, a user operating terminal 406) in view of applicable MIMO channel configuration parameters. For example, signals 410 and 412 transmitted from base stations 402 and 404 may employ selected antenna elements for each of the base stations based on the coding scheme and/or MIMO scheme that is currently employed for a particular subscriber. In general, cooperative MIMO transmissions can be performed during regular communication, or during handoff, where a subscriber moves across the boundary between cells.

[0044] In one embodiment, space-time coding is employed. For example, incoming information bits are space-time coded (using *e.g.*, space-time block or trellis codes) at block 408, and the encoded data are forwarded to each of base stations 402 and 404. Further details of space-time block encoding and the use of space-time trellis codes are discussed below.

[0045] In one embodiment, the space-time (or space-frequency, or space-time-frequency) coding is performed at a master encoder. In another embodiment, the space-time (or space-frequency, or space-time-frequency) is performed at separate locations (*e.g.*, within the base stations) based on a common (replicated) information bit sequence received at each of the separate locations.

[0046] Figure 4b shows uplink signal processing aspects of cooperative MIMO architecture 400. In this instance, an uplink signal 414 is transmitted from terminal 406 via selected antennas from among transmit antennas 1-Nt. The uplink

signal 414 is received by the respective receive antenna arrays (1-Nr_1, 1-Nr_2) for base stations 402 and 404. (It is noted that the same antennas may be used for both transmit and receive operations for some embodiments, while separate sets of transmit and receive antennas may be employed for other embodiments.) Upon being received at the base stations, initial signal processing is performed on the uplink signals, and the processed signals are forwarded to a block 416 to perform joint MIMO decoding and demodulation, thus extracting the information bits corresponding to the data transmitted by terminal 406. In general, the components for performing the operations of block 416 may be implemented in a master decoder that is centrally located with respect to multiple base stations (*e.g.*, base stations 402 and 404), or may be located at one of the multiple base stations.

[0047] Figure 5 depicts a multi-user cooperative MIMO architecture 500. Under this embodiment, the augmented antenna array (comprising selected transmit antenna elements for base stations 502 and 504) is used to perform MIMO operation towards one or more intended subscribers while limiting the radio signal at the location/direction of un-intended subscribers using a beamforming and nulling scheme. For example, techniques are known for steering transmitted signals toward selected locations, while transmitted signals sent toward other directions are nullified due to signal canceling effects and/or fading effects. Collectively, these selective transmission techniques are referred to as beamforming, and are accomplished by using appropriate antenna elements (an augmented array of antennas hosted by two or more base stations under the embodiments herein) and applicable control of the signals transmitted from those antenna elements (*e.g.*, via weighted inputs derived from feedback returned from a targeted terminal). Under beamforming embodiments of the invention, current techniques employed for antenna arrays located at a single base stations (see, *e.g.*, D. J. Love, R. W. Heath Jr., and T. Strohmer, "Grassmannian Beamforming for Multiple-Input Multiple-Output Wireless Systems," IEEE Transactions on Information Theory, vol. 49, pp. 2735–2747, Oct. 2003) are extended to support beamforming operations via selected antenna elements hosted by multiple base stations. As described below, it may be necessary to employ signal synchronization between multiple base stations to obtain the desired beamforming results.

[0048] In the embodiment of Figure 5, information bits are encoded using one of space- time, space-frequency, or space-time-frequency coding schemes in a block 514. Block 514 is also employed to perform beamforming operations, as describe below in further detail with reference to Figure 7b. The encoded output of block 514 is then provided to each of base stations 502 and 504, which in turn transmit respective signals 516 and 518. As depicted by lobes 520, 522, and 524, the channel characteristics of the combined signals 516 and 518 produce areas of higher gain in certain directions. At the same time, the gain of the combined signals 516 and 518 in other directions, such as depicted by a null direction 526, may be greatly reduced (*e.g.*, to the point at which the signal cannot be decoded) due to spatial nulling. In one embodiment, spatial nulling is performed at the direction of un-intended subscribers.

[0049] For example, under the scenario illustrated in Figure 5, the combined signals 516 and 518 are controlled so as to produce a high gain within lobe 522. As such, terminal 506 receives a good signal at its antenna array, and can decode the combined MIMO signal using appropriate MIMO decoding techniques that are well-known in the wireless communication system arts. Meanwhile, the strength of the combined signal received at a terminal 528 is nulled using spatial nulling. Accordingly, data corresponding to the information bits received at block 514 is transmitted to only terminal 506, and is not received by terminal 528.

[0050] Figure 6 depicts another multi-user cooperative MIMO architecture 600. Instead of forming nulls to un-intended terminals, information from multiple users is jointed encoded, transmitted from multiple base stations via the augmented MIMO antenna array, and then decoded at the receiving terminals. In one embodiment of the invention, the information is decoded at the user ends independently. The signals intended for other users are treated as interference. In another embodiment, the information from all users are decoded jointly. In yet another embodiment, the information received at different user locations are consolidated for joint decoding.

[0051] The embodiment of Figure 6 shows an example of joint decoding. In this instance, information to be sent to terminals 1 (606) and 2 (628) is jointly encoded using one of space-time, space-frequency, or space-time-frequency coding in a block 630. For clarity, the respective information to be sent to terminals 1 and 2 is

depicted as data A and data B. The jointly encoded output of block 630 is provided as inputs to each of base stations 602 and 604. The base stations then transmit the jointly encoded data via selected antennas (corresponding to MIMO channels assigned to terminals 1 and 2) to terminals 606 and 628. Upon receipt of the jointly encoded data, it is decoded via operations performed in a block 632 for each of terminals 606 and 628. Upon being decoded, information intended for each recipient terminal is kept, while other information is discarded. Accordingly, terminal 606 keeps data A and discards data B, while terminal 628 keeps data B and discards data A. In one embodiment, information to keep and discard is identified by packet headers corresponding to packets that are extracted from the decoded data received at a given terminal.

[0052] A block diagram corresponding to one embodiment of an OFDMA (Orthogonal Frequency Division Multiple Access) encoding/transmitter module 700A for a base station having N_t transmit antennas is shown in Figure 7a. Information bits for each of 1-N subcarriers are received at respective space-time coding (STC) blocks 704_{1-N}. The size of the STCs is a function of the number of transmit antennas N_t. In general, the space-time codes may comprise space-time trellis codes (STTC), space-time block codes (STBC), as well as STTC or STBC with delay diversity, details of which are described below. Based on the applicable STC, each of blocks 704_{1-P} outputs a set of code words $c_1[j,k]$ to $c_{Nt}[j,k]$, whereby j represents the sub-channel index and k is the time index. Each of the code words is then forwarded to an appropriate Fast Fourier Transform (FFT) blocks 706_{1-Nt}. The outputs of the FFT blocks 706_{1-Nt} are then fed to parallel to serial (P/S) conversion blocks 708_{1-Nt}, and cyclic prefixes are added via add cyclic prefix (CP) blocks 710_{1-Nt}. The outputs of add CP blocks 710_{1-Nt} are then provided to transmit antennas 1-N_t to be transmitted as downlink signals to various terminals within the base station's coverage area.

[0053] A block diagram corresponding to one embodiment of an OFDMA receiver/decoder module 800 for a terminal having N_r receive antennas is shown in Figure 8. The signal processing at the receive end of a downlink signal is substantially the inverse of the process used for encoding and preparing the signal for transmission. First, the cyclic prefix for each of the signals received at respective receive antennas 1-N_r is removed by a respective remove CP block blocks 810_{1-Nr}. The respective signals are then fed into respective serial-to-parallel (S/P) conversion blocks 808_{1-Nt} to produce

parallel sets of data, which are then provided as inputs to FFT blocks $806_{1\text{-}Nr}$. The outputs of FFT blocks $806_{1\text{-}Nr}$ are then forwarded to appropriate STC decoding blocks $804_{1\text{-}N}$ for decoding. The decoded data is then output at the information bits for subcarriers 1-N.

[0054] A block diagram corresponding to one embodiment of an OFDMA encoding/beamforming/transmitter module 700B that performs beamforming is shown in Figure 7b. As depicted by like-numbered blocks, much of the signal processing performed by the embodiments of Figures 7a and 7b is similar. In addition to these processing operations, OFDMA encoding/beamforming/transmitter module 700B further includes beamforming blocks $705_{1\text{-}N}$. Each of these beamforming blocks applies a weighted value $W_{1\text{-}N}$ to its respective inputs in view of control information provided by a beamforming control block 712, which is generated in response to beamforming feedback data 714. Further differences between the embodiments of Figure 7a and 7b include STC blocks $704A_{1\text{-}N}$, which now employ STCs having a size L, which represents the number of beamforming channels.

SPACE TIME ENCODING

[0055] Space-Time Codes (STC) were first introduced by Tarokh *et al.* from AT&T research labs (V. Tarokh, N. Seshadri, and A. R. Calderbank, Space-time codes for high data rates wireless communications: Performance criterion and code construction," IEEE Trans. Inform. Theory, vol. 44, pp. 744–765, 1998) in 1998 as a novel means of providing transmit diversity for the multiple-antenna fading channel. There are two main types of STCs, namely space-time block codes (STBC) and space-time trellis codes (STTC). Space-time block codes operate on a block of input symbols, producing a matrix output whose columns represent time and rows represent antennas. Space-time block codes do not generally provide coding gain, unless concatenated with an outer code. Their main feature is the provision of full diversity with a very simple decoding scheme. On the other hand, space-time trellis codes operate on one input symbol at a time, producing a sequence of vector symbols whose length represents antennas. Like traditional TCM (trellis coded modulation) for a single-antenna channel, space-time trellis codes provide coding gain. Since they also provide full diversity gain, their key advantage over space-time block codes is the provision of coding gain. Their disadvantage is that they are difficult to design and generally require high complexity encoders and decoders.

[0056] Figure 9 shows a block diagram of as STC MIMO transmission model. Under the model, data from an information source 900 is encoded using a STBC or STTC code by a space-time encoder 902. The encoded data is then transmitted over a MIMO link 904 to a receiver 906. The received signals are then decoded at the receiver to extract the original data.

[0057] An exemplary 8-PSK 8-state space-time trellis code for two antennas is shown in Figure 10, while an exemplary 16-QAM 16-state STTC for two antennas is shown in Figure 11. The encoding for STTCs are similar to TCM, except that at the beginning and the end of each frame, the encoder is required to be in the zero state. At each time t, depending on the state of the encoder and the input bits, a transition branch is selected. If the label of the transition branch is $c_1^t; c_2^t :::; c_n^t$, then transmit antenna i is used to send the constellation symbols $c_i^t, i = 1;2;:::;n$ and all these transmissions are in

parallel. In general, an STTC encoder may be implemented via a state machine programmed with states corresponding to the trellis code that is to be implemented.

[0058] Figure 12 shows a block diagram corresponding to an STBC model employing two antennas. As before, data is received from an information source 1200. Space time block encoding is then performed by the operations of space time block code 1202 and constellation maps 1204A and 1204B.

[0059] In further detail, an STBC is defined by p x n transmission matrix G, whose entries are linear combinations of $x_1;:::;x_k$ and their conjugates $x_1^*;:::;x_k^*$; and whose columns are pairwise-orthogonal. In the case when $p = n$ and $\{x_i,\}$ are real, G is a linear processing orthogonal design which satisfies the condition that $G^TG = D$, where D is a diagonal matrix with the $(i; i)$th diagonal element of the form $(l_1^i x_1^2 + l_2^i x_2^2 + ... + l_n^i x_n^2)$ with the coefficients $l_1^i, l_2^i, ... l_n^i \rangle 0$. An example of a 2 x 2 STBC code is shown in Figure 12.

[0060] Another signal diversity scheme is to employ a combination of STC with delay. For example, Figures 13a and 13b respectively show models corresponding to an STTC with delay transmission scheme and an STBC with delay transmission scheme. In Figure 13 a, data from an information source 1300 is received by a code repetition block 1302, which produces a pair of replicated symbol sequences that are generated in view of the data. A first sequence of symbols is forwarded to an STTC encoder 1304A for encoding. Meanwhile, the replicated sequence of symbols is fed into a delay block 1306, which produces a one-symbol delay. The delayed symbol sequence output of delay block 1306 is then forwarded to STTC encoder 1304B for encoding. An exemplary 8-PSK 8-state delay diversity code for two antennas is shown in Figure 14. As illustrated, the symbol sequence for transmission antenna Tx2 is synchronized with the input sequence, while the symbol sequence for transmission antenna Txl is delayed by one symbol.

[0061] Under the signal diversity scheme of Figure 13b, data from information source 1300 is received at best block code selection logic 1308, which outputs replicated block codes to produce two block code sequences. The first block code sequence is forwarded to constellation mapper 1310A for encoding, while the

second block code sequence is delayed by one symbol via a delay block 1312 and then forwarded to constellation mapper 1310B for encoding. The encoded signals are then transmitted via first and second transmit antennas.

[0062] The foregoing STTC and STBC schemes are depicted herein in accordance with conventional usage for clarity. Under such usage, the various encoded signals are transmitted using multiple antennas at the *same* base station. In contrast, embodiments of the invention employ selective antenna elements in antenna arrays from multiple base stations to form an augmented MIMO antenna array.

[0063] In order to implement an STC transmission scheme using multiple base stations, additional control elements may be needed. For example, if the base stations are located at different distances from a master encoder facility, there may need to be some measure to synchronize the antenna outputs in order to obtain appropriate MIMO transmission signals. Likewise, appropriate timing must be maintained when implementing a delay diversity scheme using antenna arrays at base stations at different locations.

[0064] Figure 15 shows a cooperative MIMO architecture 1500 that employs a master encoder 1502. In general, the master encoder 1502 may be located at a separate facility from base stations 402 and 404, or may be co-located with one of the base stations. In respective embodiments, master encoder 1502 performs STC encoding and signal processing operations similar to the operations performed by the OFDMA encoding/transmitter module 700A of Figure 7A (as depicted in Figure 15) or OFDMA encoding/beamforming/transmitter module 700B of Figure 7B. However, the transmission output are not fed directly to the transmission antennas, since the transmission antennas for at least one of the base stations will be located at a separate facility. Rather, master encoder 1502 produces respective sets of antenna drive signals 1504 and 1506 for base stations 402 and 404. Upon receipt of the antenna drive signals, corresponding downlink signals are transmitted by selected antennas hosted by base stations 402 and 404 based on the different MIMO channels supported by the system. Control inputs to master encoder 1502 corresponding to the MIMO channels are provided by a subscriber MIMO channel assignment register 1508.

[0065] If necessary, signal synchronization is performed by one or more sync/delay blocks 1510. For example, in the embodiment of Figure 15, two sync/delay blocks 1510A and 1510B are shown, with each being employed at a respective base station. In other embodiments, some base stations may not require a delay block, particularly if a co-located master encoder is employed. In general, the sync/delay blocks for a system are employed to synchronize the antenna signals or synchronize the delay of antenna signals (when delay diversity is employed).

[0066] Signal synchronization may be performed in any number of ways using principles known in the communication arts. For example, in one embodiment separate timing signals or sequences are provided to each of the base stations in a cooperative MIMO system. The timing signals or sequences contain information from which corresponding antenna drive signals may be synchronized. To perform such synchronization, each sync/delay blocks add an appropriate delay to its antenna signals. Synchronization feedback information may also be employed using well-known techniques.

[0067] Under one embodiment of a variation of architecture 1500, antenna signal processing operations corresponding to the FFT, P/S, and add CP blocks are implemented at the respective base stations. In this instance, STC code sequences are provided to each of the base stations, with further antenna signal processing being performed at the base stations. Under this approach, timing signals or the like may be embedded in the data streams containing the code sequences.

[0068] Another approach for implementing an cooperative MIMO system is depicted by cooperative MIMO architecture 1600 in Figure 16. Under this architecture, replicated instances of input information streams for multiple channel subscribers are generated by a block 1602 and provided to each of the base stations used to form the augmented MIMO antenna array. In this case, the STC encoding and signal processing operations are performed at each base station in a manner similar to that described with respect to the OFDMA encoding/transmitter module 700A of Figure 7 A (as depicted in Figure 16) or OFDMA encoding/beamforming/transmitter module 700B of Figure 7B.

[0069] In one embodiment, subscriber MIMO channel information is embedded in the input data streams received at each base station. Accordingly, there is a

need to determine which antenna elements are used to support each MIMO channel. This information is stored in a subscriber MIMO channel register 1604, and is used to control signal processing in a collaborative manner at the base stations.

[0070] As before, there may be a need to synchronize the antenna signals. For example, if the components used to perform the operations of block 1602 are located at different distances from the base stations, the input streams will be received at different times. In response, the corresponding antenna signals will be generated at different times. To address this situation, one or more sync/delay blocks 1606 may be employed (*e.g.*, as depicted by sync/delay blocks 1606A and 1606B in Figure 16B. In one embodiment, timing signals are encoded in the input data streams using one of many well-known schemes. The timing signals, which may typically comprise timing frames, timing bits, and/or timing sequences, are extracted by 1606A and 1606B. In view of the timing information, a variable delay is applied by sync/delay block for the data streams that are received earlier, such that at the point the data streams are ready received at the STC blocks, they have been resynchronized.

[0071] In general, the processing operations performed by the process blocks depicted herein may be performed using known hardware and/or software techniques. For example, the processing for a given block may be performed by processing logic that may comprise hardware (circuitry, dedicated logic, *etc.*), software (such as is run on a general purpose computer system or a dedicated machine), or a combination of both.

[0072] Whereas many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description, it is to be understood that any particular embodiment shown and described by way of illustration is in no way intended to be considered limiting. Therefore, references to details of various embodiments are not intended to limit the scope of the claims which in themselves recite only those features regarded as essential to the invention.

CLAIMS

We claim:

1. A method comprising:

employing antenna elements from a plurality of base stations to support cooperative multiple-input multiple-output (MIMO) transmissions in a wireless network.

2. The method of claim 1, wherein the cooperative MIMO transmissions comprise orthogonal frequency division multiple access (OFDMA) MIMO transmissions.

3. The method of claim 1, further comprising encoding the cooperative MIMO transmissions using space-time coding.

4. The method of claim 3, wherein the space-time coding comprises space-time trellis coding.

5. The method of claim 3, wherein the space-time coding comprises space-time block coding.

6. The method of claim 3, further comprising encoding the cooperative MIMO transmissions using space-time coding with delay diversity.

7. The method of claim 1, further comprising encoding the cooperative MIMO transmissions using space-frequency coding.

8. The method of claim 1, further comprising encoding the cooperative MIMO transmissions using space-time-frequency coding.

9. The method of claim 1, further comprising performing spatial multiplexing on the cooperative MIMO transmissions.

10. The method of claim 1, wherein the cooperative MIMO transmissions include downlink transmissions from the plurality of base stations to terminals and uplink transmissions from the terminals to the plurality of base stations.

11. The method of claim 1, further comprising performing spatial beamforming for selected MIMO transmissions.

12. The method of claim 11, further comprising performing spatial beamforming in combination with one of space-time, space-frequency and space-time-frequency coding of the selected MIMO transmissions.

13. The method of claim 1, further comprising transmitting a cooperative MIMO transmission to at least two terminals simultaneously.

14. The method of claim 13, further comprising performing spatial beamforming on the cooperative MIMO transmissions such that MIMO transmissions are directed toward intended users while spatial nulling is effected toward unintended users.

15. The method of claim 1, further comprising jointly decoding uplink MIMO transmissions received from multiple terminals.

16. The method of claim 1, further comprising jointly decoding downlink MIMO transmissions received at multiple terminals.

17. The method of claim 1, further comprising separately decoding uplink MIMO transmissions received from multiple terminals.

18. The method of claim 1, further comprising jointly encoding downlink MIMO transmissions sent to multiple terminals.

19. The method of claim 18, further comprising:

decoding a jointly encoded downlink MIMO transmission at a terminal; and keeping portions of data sent via jointly encoded downlink MIMO transmission intended for the terminal, while discarding other portions of data that are not intended for the terminal.

20. The method of claim 18, further comprising separately decoding the jointly encoded downlink transmissions at each of the multiple terminals.

21. The method of claim 1, further comprising:

generating antenna drive signals via at a first facility;

sending respective portions of the antenna drive signals to each of the base stations; and

performing cooperative MIMO transmissions by driving selected antenna elements at the base stations with the respective portion of the antenna drive signals sent to those base stations.

22. The method of claim 21, wherein the first facility is co-located with one of the base stations.

23. The method of claim 21, further comprising synchronizing transmission of the respective portions of antenna drive signals sent to the base stations.

24. The method of claim 1, further comprising:

replicating a data stream received from an information source;

forwarding a replication of the data stream to each base station;

performing antenna signal processing operations at each base station on the data stream it receives to generate antenna signals; and

transmitting the antenna signals over selected antenna elements at each of the base station to form a cooperative MIMO transmission.

25. The method of claim 24, further comprising synchronizing performing the antenna signal processing operations at the base stations such that the generated antenna signals are transmitted over the selected antenna elements at different base stations in synchrony.

26. The method of claim 1, further comprising performing cooperative MIMO transmissions to facilitate terminal handoff between wireless network cells or sectors.

27. The method of claim 1, further comprising:

performing MIMO encoding on a data stream to be transmitted over a corresponding cooperative MIMO channel, the MIMO encoding producing respective sets of encoded data sequences on which antenna signal processing is to be performed at respective base stations;

sending each respective set of encoded data sequences to its corresponding base station; and

performing antenna signal processing operations to generate antenna signals at each of the base stations in view of the set of encoded data sequences received by that base station; and

transmitting the antenna signals over corresponding antenna elements at each of the base station to transmit the data stream over the cooperative MIMO channel.

28. The method of claim 27, further comprising synchronizing performing the antenna signal processing operations at the base stations such that the generated antenna signals are transmitted over the selected antenna elements at different base stations in synchrony.

29. A multicell wireless network, comprising:

a plurality of base stations, each associated with a respective cell and having a respective antenna array including at least one antenna element; and

a cooperative multiple-input multiple-output (MIMO) transmission mechanism that employs selected antenna elements from the plurality of base stations to form an augmented antenna array used to support cooperative MIMO transmissions over the wireless network.

30. The multicell wireless network of claim 29, wherein the cooperative MIMO transmissions comprises orthogonal frequency division multiple access (OFDMA) MIMO transmissions.

31. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism encodes the cooperative MIMO transmissions using space-time coding.

32. The multicell wireless network of claim 31, wherein the space-time coding comprises space-time trellis coding.

33. The multicell wireless network of claim 31, wherein the space-time coding comprises space-time block coding.

34. The multicell wireless network of claim 31, wherein the cooperative MIMO transmission mechanism encodes the cooperative MIMO transmissions using space-time coding with delay diversity.

35. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism encodes the cooperative MIMO transmissions using space-frequency coding.

36. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism encodes the cooperative MIMO transmissions using space-time-frequency coding.

37. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism performs spatial multiplexing on the cooperative MIMO transmissions.

38. The multicell wireless network of claim 29, wherein the cooperative MIMO transmissions include downlink transmissions from the plurality of base stations to terminals and uplink transmissions from the terminals to the plurality of base stations.

39. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism performs spatial beamforming for selected MIMO transmissions.

40. The multicell wireless network of claim 39, wherein the cooperative MIMO transmission mechanism performs spatial beamforming in combination with one

of space-time, space-frequency and space-time-frequency coding of the selected MIMO transmissions.

41. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism performs transmitting a cooperative MIMO transmission to at least two terminals simultaneously.

42. The multicell wireless network of claim 41, wherein the cooperative MIMO transmission mechanism further performs spatial beamforming on the cooperative MIMO transmissions such that MIMO transmissions are directed toward intended users while spatial nulling is effected toward unintended users.

43. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism further performs jointly decoding uplink MIMO transmissions received from multiple terminals.

44. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism further performs separately decoding uplink MIMO transmissions received from multiple terminals.

45. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism further performs jointly encoding downlink MIMO transmissions sent to multiple terminals.

46. The multicell wireless network of claim 29, further comprising:

a cooperative MIMO master encoder to:

generate antenna drive signals; and

send respective portions of the antenna drive signals to each of the base stations;

wherein cooperative MIMO transmissions are performed by driving selected antenna elements at the base stations with the respective portion of the antenna drive signals sent to those base stations.

47. The multicell wireless network of claim 46, wherein the cooperative MIMO master encoder is co-located with one of the base stations.

48. The multicell wireless network of claim 46, further comprising a synchronizing mechanism to synchronize transmission of the respective portions of antenna drive signals sent to the base stations.

49. The multicell wireless network of claim 29, further comprising:

a data replicator to:

replicate a data stream received from an information source; and forward a replication of the data stream to each base station; and a set of antenna signal processing components at each base station to perform antenna signal processing operations on the data stream it receives to generate antenna signals, wherein the antenna signals are transmitted over selected antenna elements at each of the base station to form a cooperative MIMO transmission.

50. The multicell wireless network of claim 49, further comprising a synchronizing mechanism to synchronize the antenna signal processing operations at the base stations such that the generated antenna signals are transmitted over the selected antenna elements at different base stations in synchrony.

51. The multicell wireless network of claim 29, further comprising:

a master encoder to:

perform MIMO encoding on a data stream to be transmitted over a corresponding cooperative MIMO channel, the MIMO encoding producing respective sets of encoded data sequences on which antenna signal processing is to be performed at respective base stations;

send each respective set of encoded data sequences to its corresponding base station; and

a set of antenna signal processing components at each base station to perform antenna signal processing operations on the set of encoded data sequences it receives to generate antenna signals,

wherein the antenna signals are transmitted over selected antenna elements at each of the base station to form a cooperative MIMO transmission over the cooperative MIMO channel.

52. The multicell wireless network of claim 51, further comprising a synchronizing mechanism to synchronize the antenna signal processing operations at the base stations such that the generated antenna signals are transmitted over the selected antenna elements at different base stations in synchrony.

53. The multicell wireless network of claim 29, wherein the cooperative MIMO transmission mechanism performs cooperative MIMO transmissions to facilitate terminal handoff between wireless network cells or sectors.

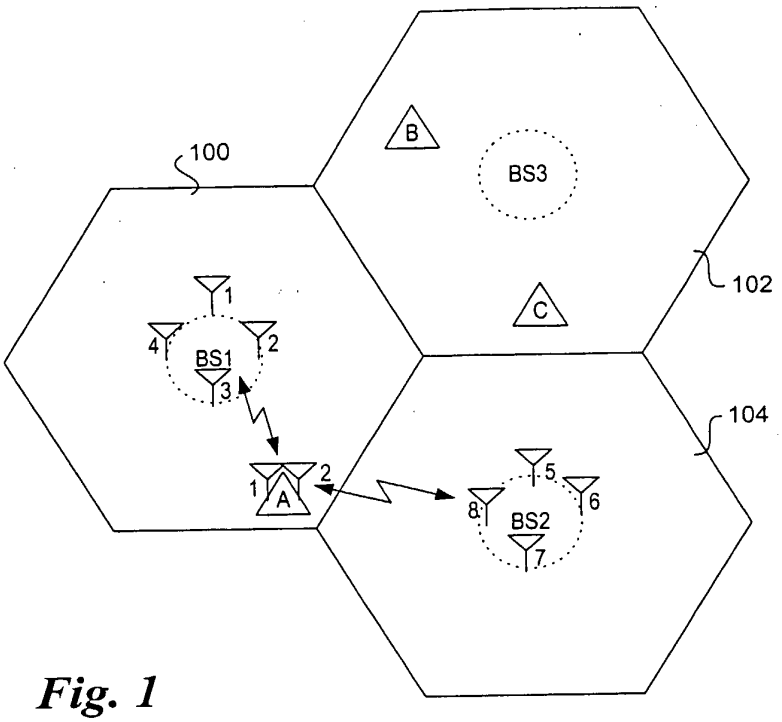

100
B
BS3
102
C
1
4
BS1
2
3
104
1
A
2
5
8
BS2
6
7

Fig. 1

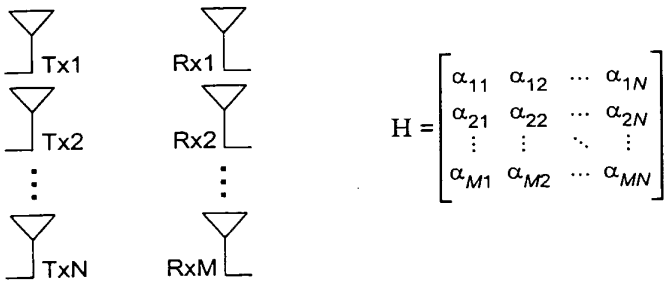

Tx1
Tx2
TxN
Rx1
Rx2
RxM
H = [α11 α12 ⋯ α1N; α21 α22 ⋯ α2N; ⋮ ⋮ ⋱ ⋮; αM1 αM2 ⋯ αMN]

Fig. 2

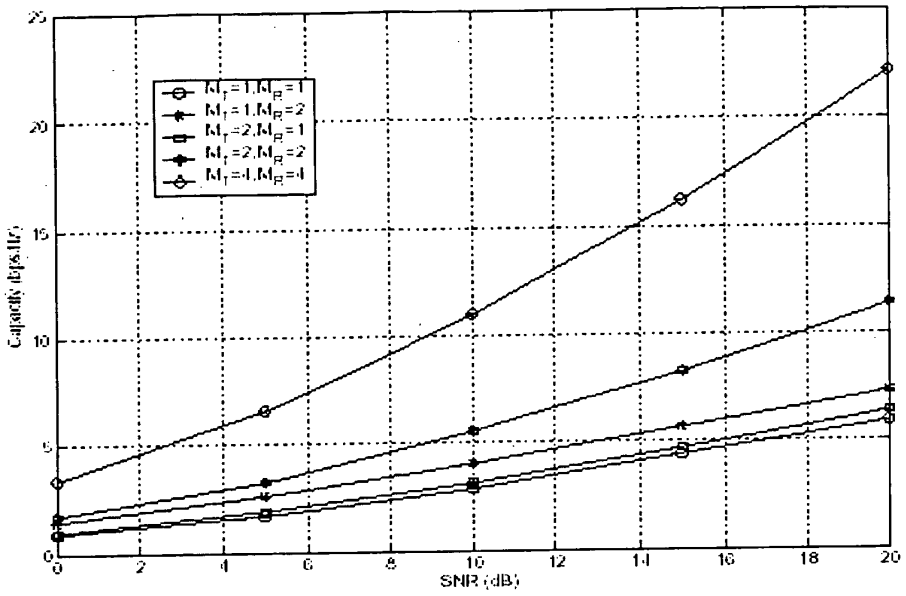

$M_T=1, M_R=1$
$M_T=1, M_R=2$
$M_T=2, M_R=1$
$M_T=2, M_R=2$
$M_T=4, M_R=4$
Capacity (bps/Hz)
SNR (dB)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20

Fig. 3

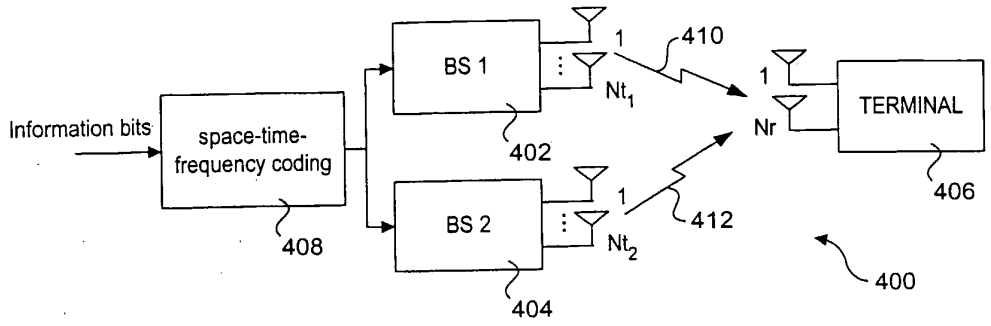

Information bits
space-time-frequency coding
408
BS 1
BS 2
402
404
1
Nt_1
Nt_2
410
412
1
Nr
TERMINAL
406
400

Fig. 4a

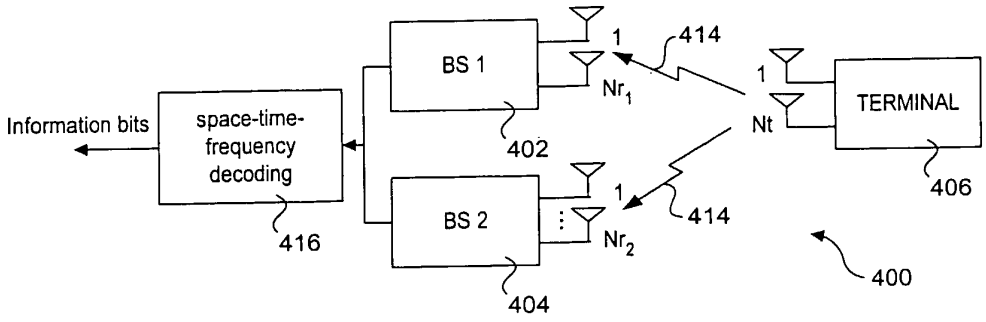

Information bits
space-time-frequency decoding
416
BS 1
BS 2
402
404
1
Nr_1
Nr_2
414
414
1
Nt
TERMINAL
406
400

Fig. 4b

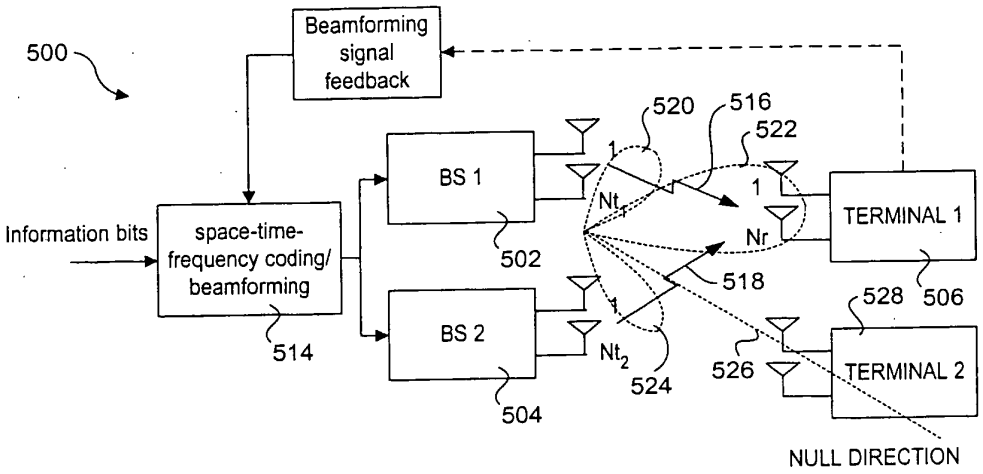

500
Beamforming signal feedback
Information bits
space-time-frequency coding/ beamforming
514
BS 1
502
BS 2
504
520
516
522
518
524
526
528
506
TERMINAL 1
TERMINAL 2
NULL DIRECTION

Fig. 5

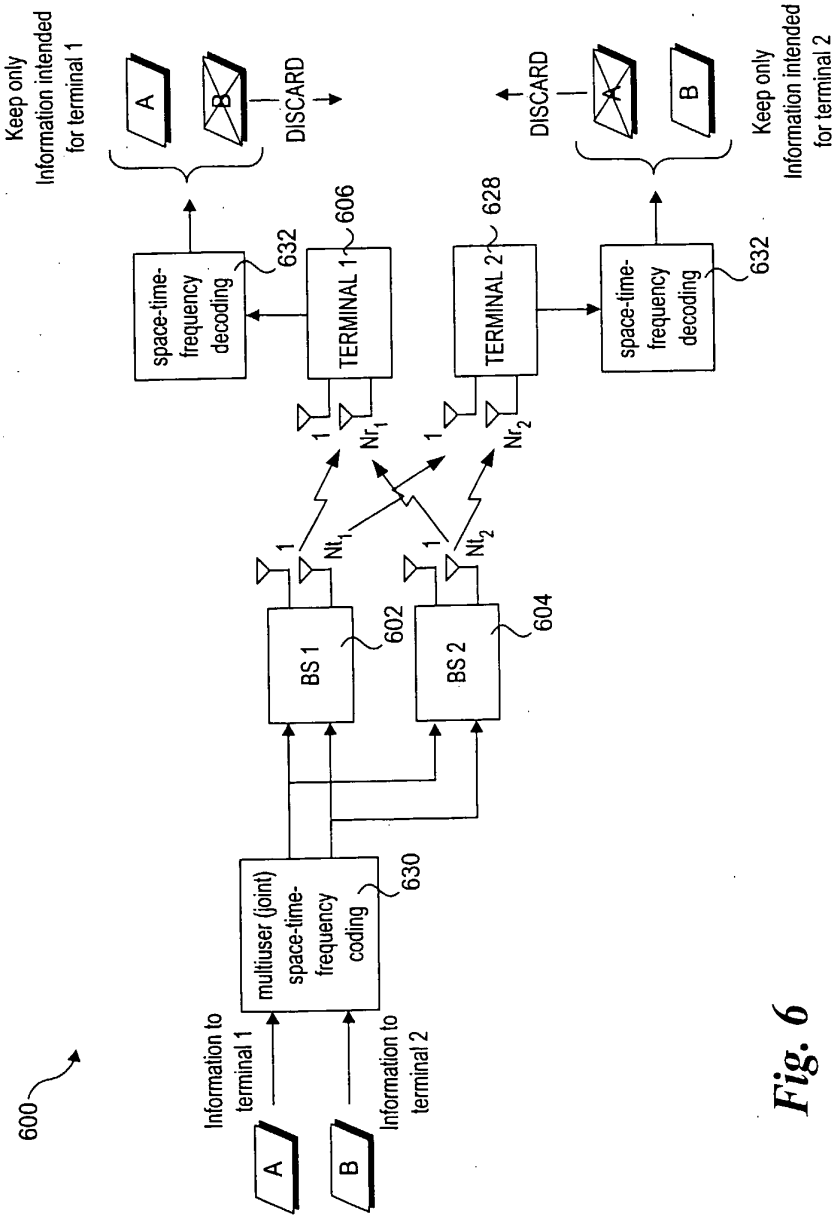

600
Information to terminal 1
Information to terminal 2
A
B
multiuser (joint) space-time-frequency coding
630
BS 1
602
BS 2
604
1
Nt1
Nt2
TERMINAL 1
606
TERMINAL 2
628
Nr1
Nr2
space-time-frequency decoding
632
DISCARD
Keep only Information intended for terminal 1
Keep only Information intended for terminal 2

Fig. 6

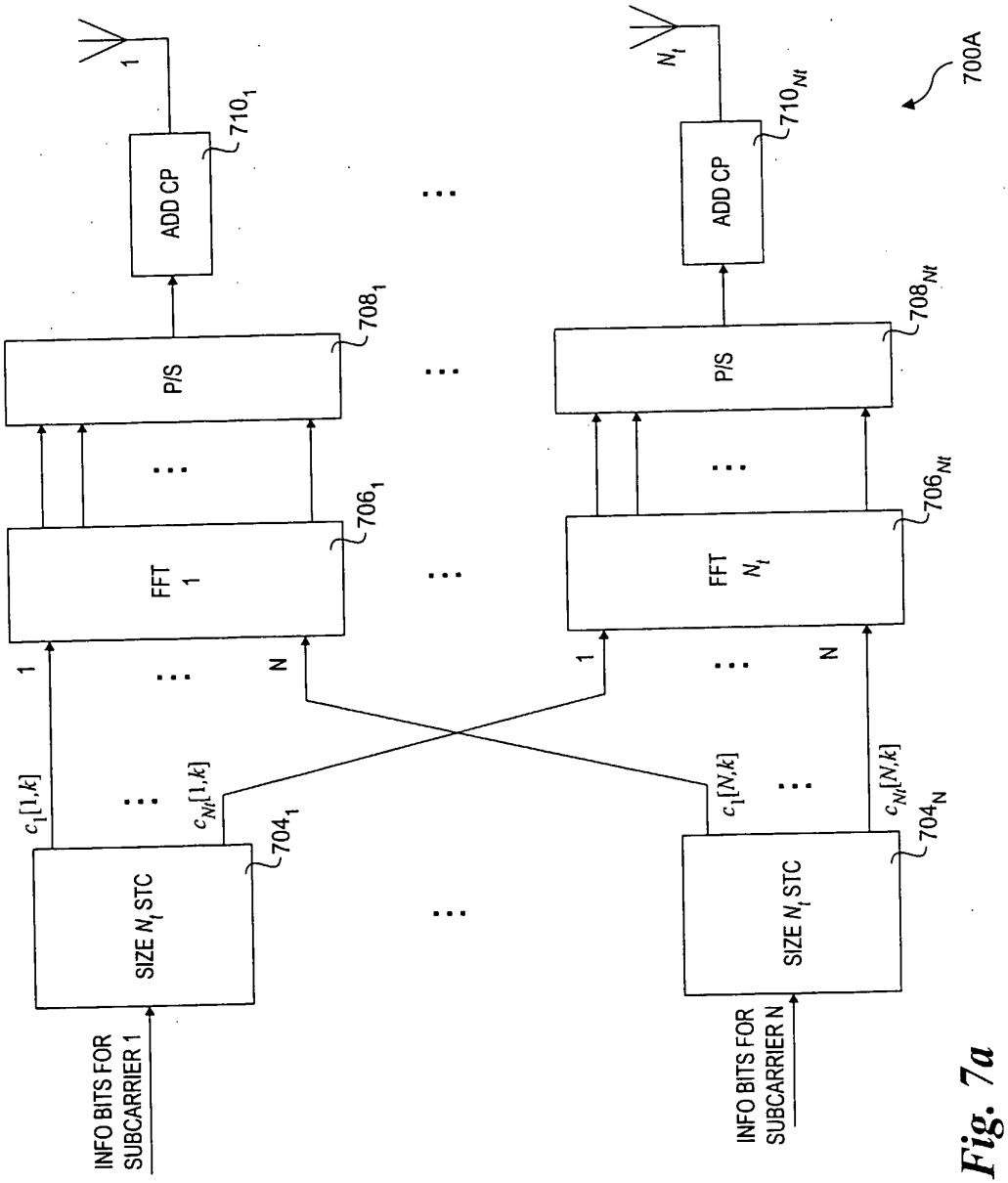

700A
INFO BITS FOR SUBCARRIER 1
INFO BITS FOR SUBCARRIER N
SIZE N_t STC
704_1
704_N
$c_1[1,k]$
$c_{Nt}[1,k]$
$c_1[N,k]$
$c_{Nt}[N,k]$
1
N
FFT 1
FFT N_t
706_1
706_{Nt}
P/S
708_1
708_{Nt}
ADD CP
710_1
710_{Nt}
1
N_t

Fig. 7a

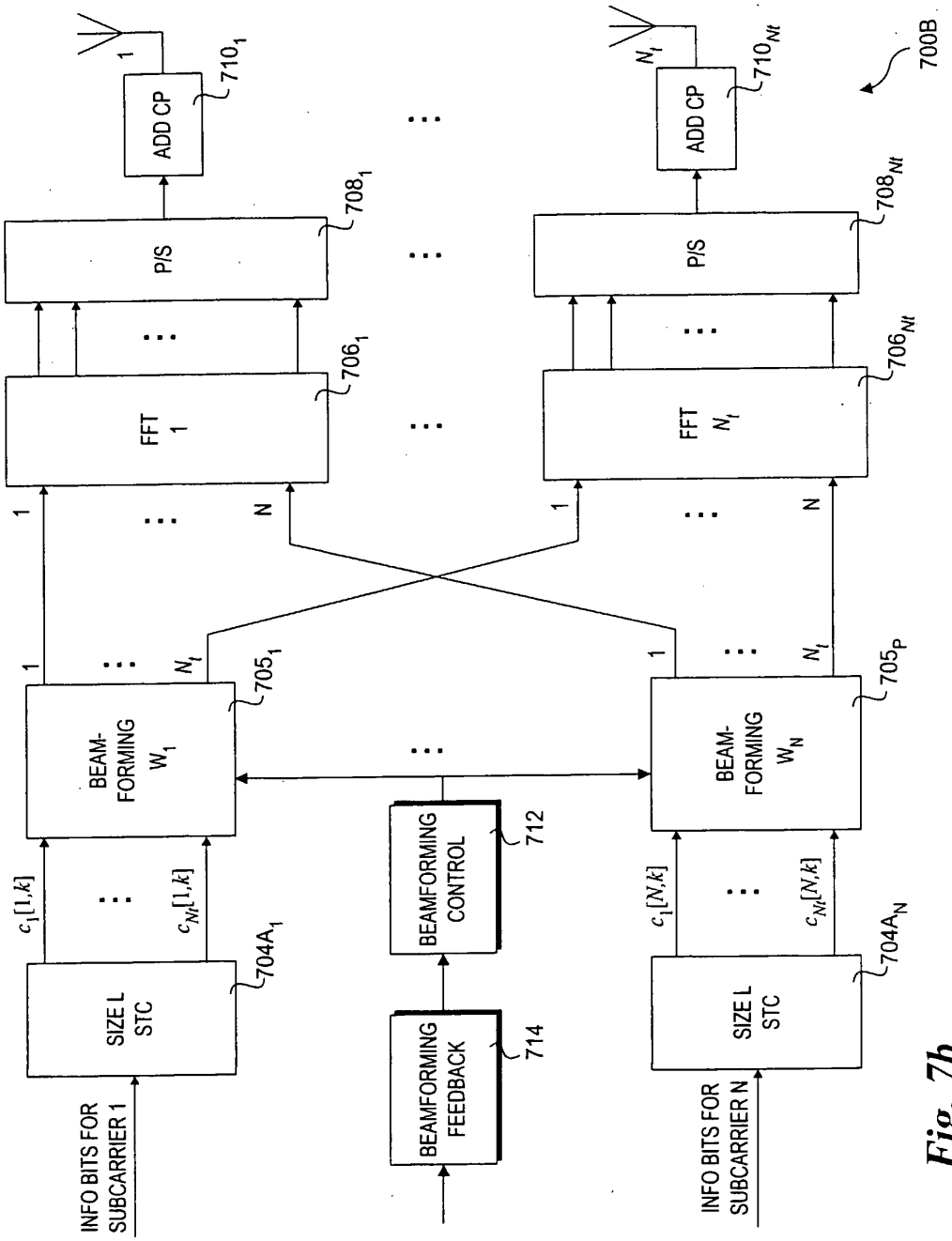

700B
INFO BITS FOR SUBCARRIER 1
INFO BITS FOR SUBCARRIER N
SIZE L STC
704A1
704AN
BEAMFORMING FEEDBACK
714
BEAMFORMING CONTROL
712
BEAM-FORMING W1
BEAM-FORMING WN
705P
FFT 1
FFT Nt
706Nt
P/S
708Nt
ADD CP
710Nt

Fig. 7b

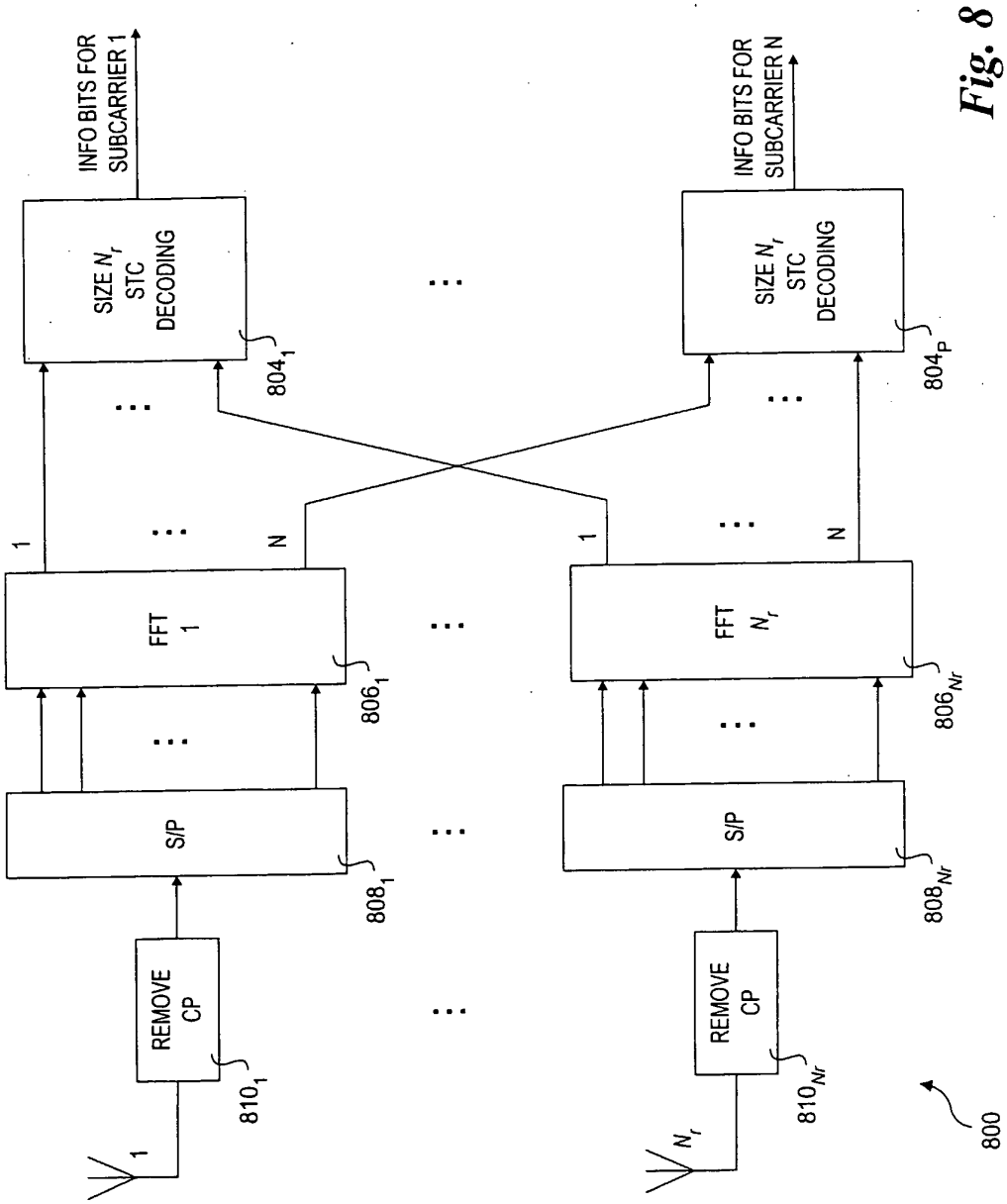

INFO BITS FOR SUBCARRIER 1
INFO BITS FOR SUBCARRIER N
SIZE N_r STC DECODING
804_1
804_P
FFT 1
FFT N_r
806_1
806_{Nr}
S/P
808_1
808_{Nr}
REMOVE CP
810_1
810_{Nr}
1
N
N_r
800

Fig. 8

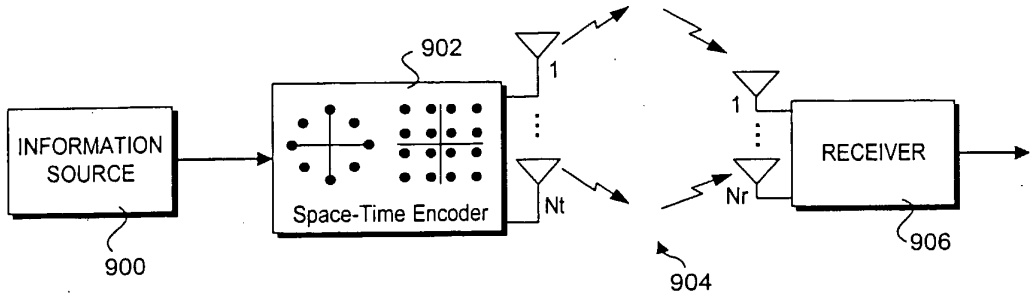

INFORMATION SOURCE
900
902
Space-Time Encoder
1
Nt
1
Nr
RECEIVER
906
904

Fig. 9

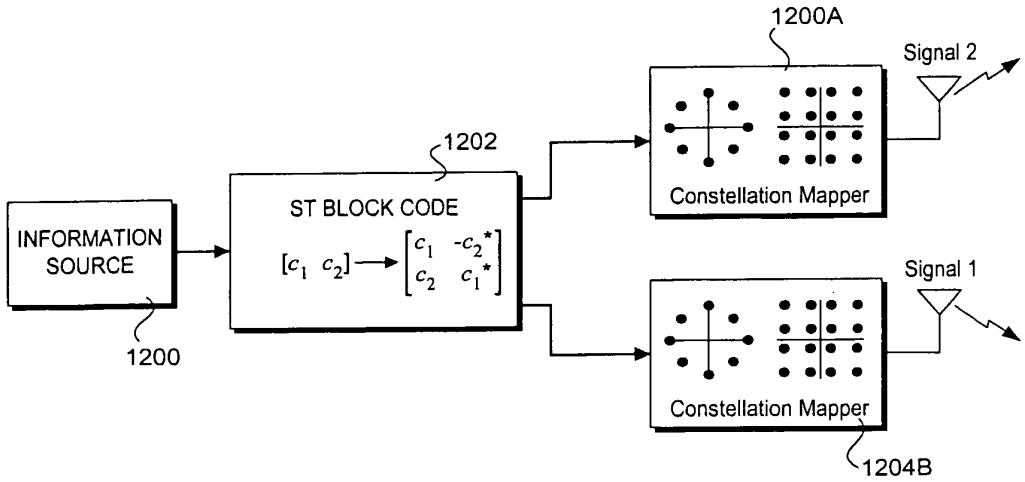

INFORMATION SOURCE
1200
1202
ST BLOCK CODE
$[c_1 \ c_2] \rightarrow \begin{bmatrix} c_1 & -c_2^* \\ c_2 & c_1^* \end{bmatrix}$
1200A
Constellation Mapper
Signal 2
Constellation Mapper
Signal 1
1204B

Fig. 12

Input: 0 1 5 7 6 4
Tx 1: 0 0 5 1 3 6
Tx 2: 0 1 5 7 6 4

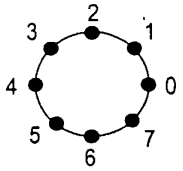
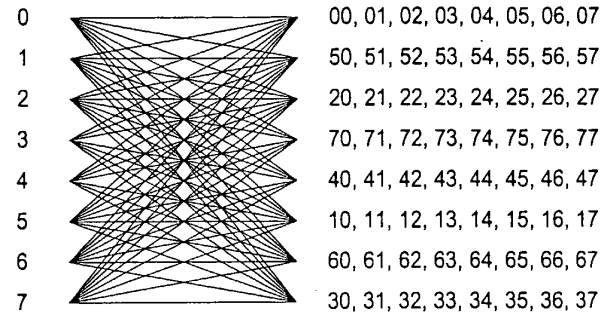


Fig. 10



8-PSK 8-State Space-Time Code with 2 Tx Antennas

Input: 0 1 5 7 6 4
Tx 1: 0 0 1 5 7 6
Tx 2: 0 1 5 7 6 4

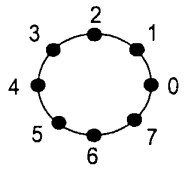
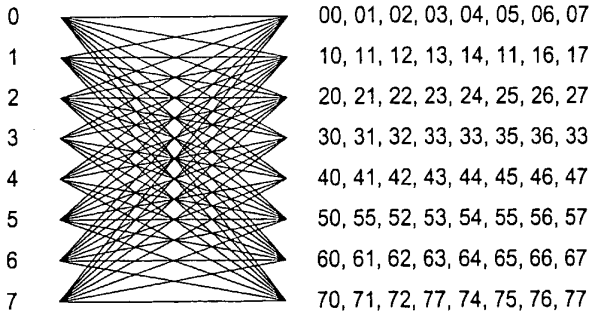


Fig. 14



8-PSK 8-State Delay Diversity Code with 2 Tx Antennas

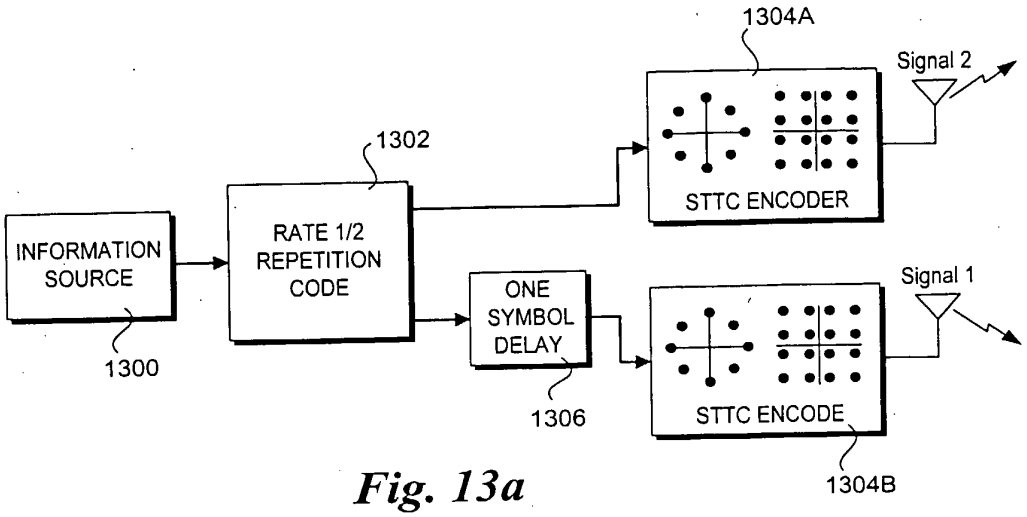


Fig. 13a

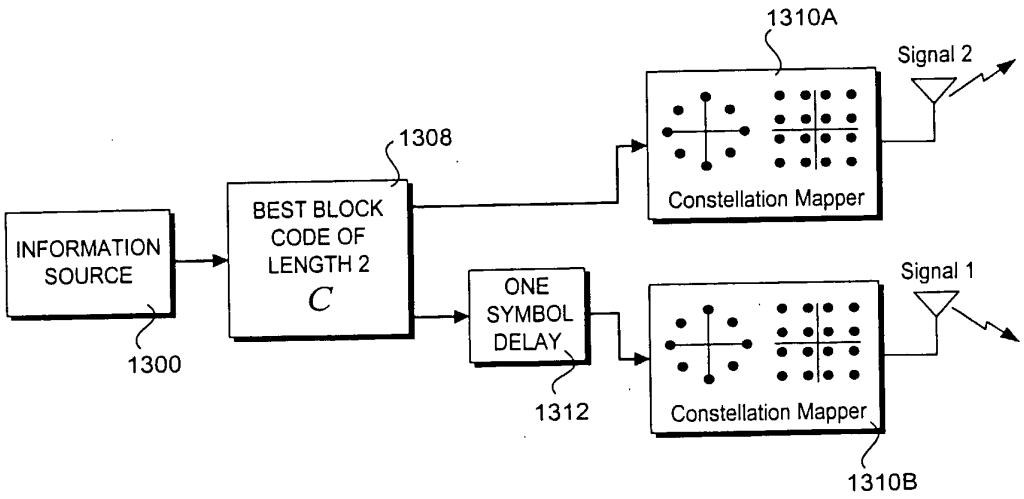
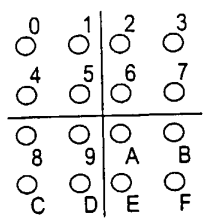
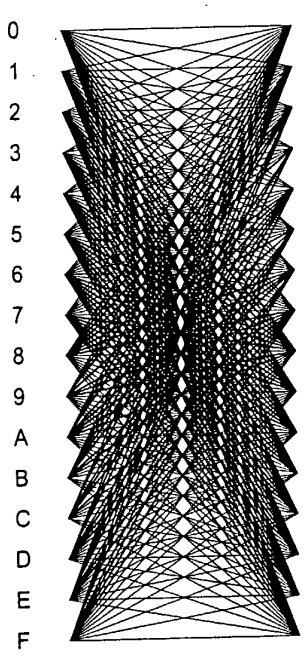


Fig. 13b



Input: 0 1 A C 5 7
Tx 1: 0 0 B A C F
Tx 2: 0 1 A C 5 7



0	00	01	02	03	04	05	06	07	08	0A	0B	0C	0D	0E	0F
1	BB	B1	B2	B3	B4	B5	B6	B7	B8	BA	BB	BC	BD	BE	BF
2	22	21	22	23	24	25	26	27	28	2A	2B	2C	2D	2E	2F
3	99	91	92	93	94	95	96	97	98	9A	9B	9C	9D	9E	9F
4	44	41	42	43	44	45	46	47	48	4A	4B	4C	4D	4E	4F
5	FF	F1	F2	F3	F4	F5	F6	F7	F8	FA	FB	FC	FD	FE	FF
6	66	61	62	63	64	65	66	67	68	6A	6B	6C	6D	6E	6F
7	DD	D1	D2	D3	D4	D5	D6	D7	D8	DA	DB	DC	DD	DE	DF
8	88	81	82	83	84	85	86	87	88	8A	8B	8C	8D	8E	8F
9	33	31	32	33	34	35	36	37	38	3A	3B	3C	3D	3E	3F
A	AA	A1	A2	A3	A4	A5	A6	A7	A8	AA	AB	AC	AD	AE	AF
B	11	11	12	13	14	15	16	17	18	1A	1B	1C	1D	1E	1F
C	CC	C1	C2	C3	C4	C5	C6	C7	C8	CA	CB	CC	CD	CE	CF
D	77	71	72	73	74	75	76	77	78	7A	7B	7C	7D	7E	7F
E	EE	E1	E2	E3	E4	E5	E6	E7	E8	EA	EB	EC	ED	EE	EF
F	55	51	52	53	54	55	56	57	58	5A	5B	5C	5D	5E	5F

16-QAM 16-State Space-Time Code with 2 Tx Antennas

Fig. 11

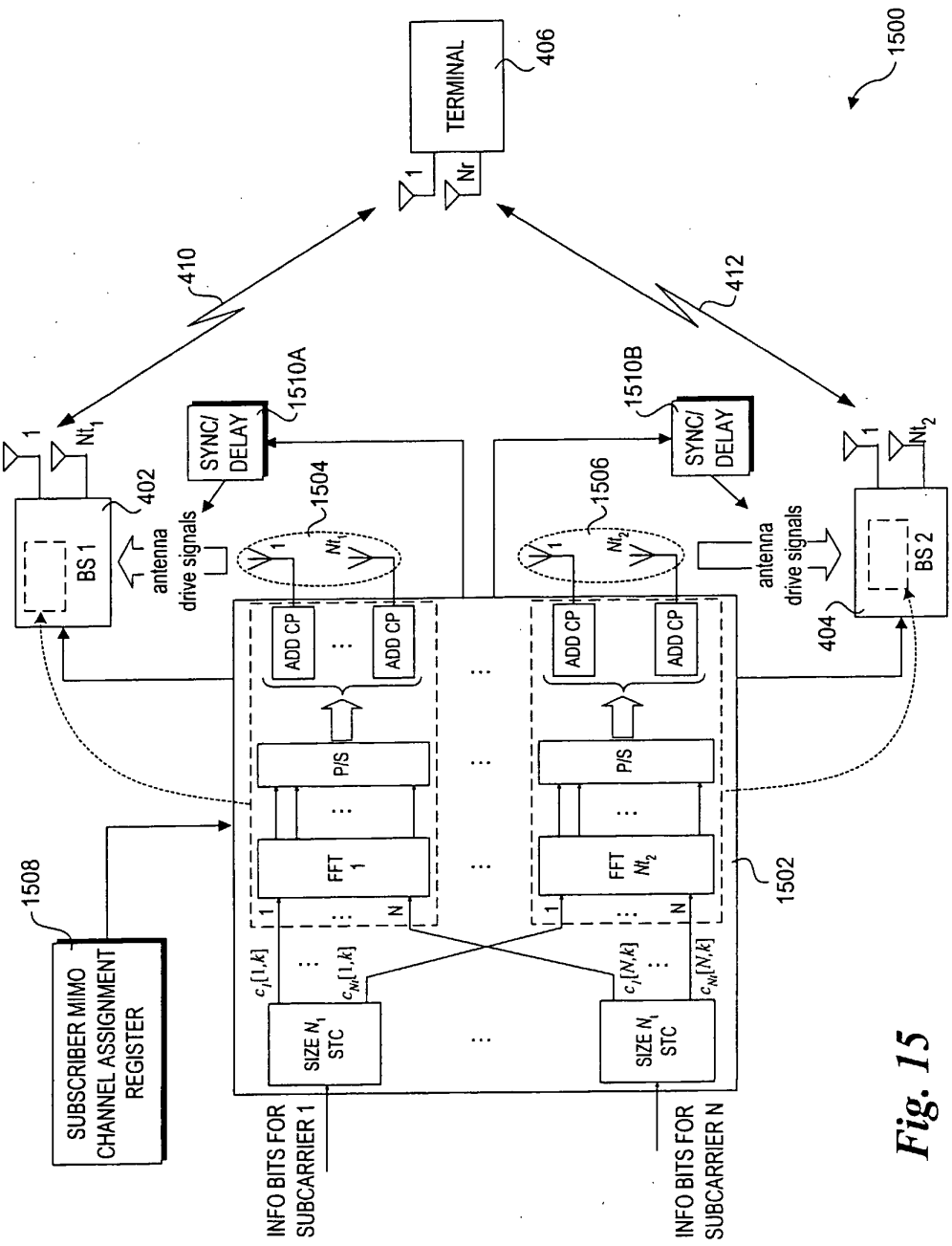

1500
TERMINAL
406
1
Nr
410
412
1510A
1510B
SYNC/ DELAY
SYNC/ DELAY
1
Nt_1
402
BS 1
antenna drive signals
1504
1506
antenna drive signals
1
Nt_2
BS 2
404
ADD CP
ADD CP
ADD CP
ADD CP
P/S
P/S
FFT 1
FFT Nt_2
1502
1508
SUBSCRIBER MIMO CHANNEL ASSIGNMENT REGISTER
SIZE N_t STC
SIZE N_t STC
$c_1[1,k]$
$c_{Nt}[1,k]$
$c_1[N,k]$
$c_{Nt}[N,k]$
INFO BITS FOR SUBCARRIER 1
INFO BITS FOR SUBCARRIER N

Fig. 15

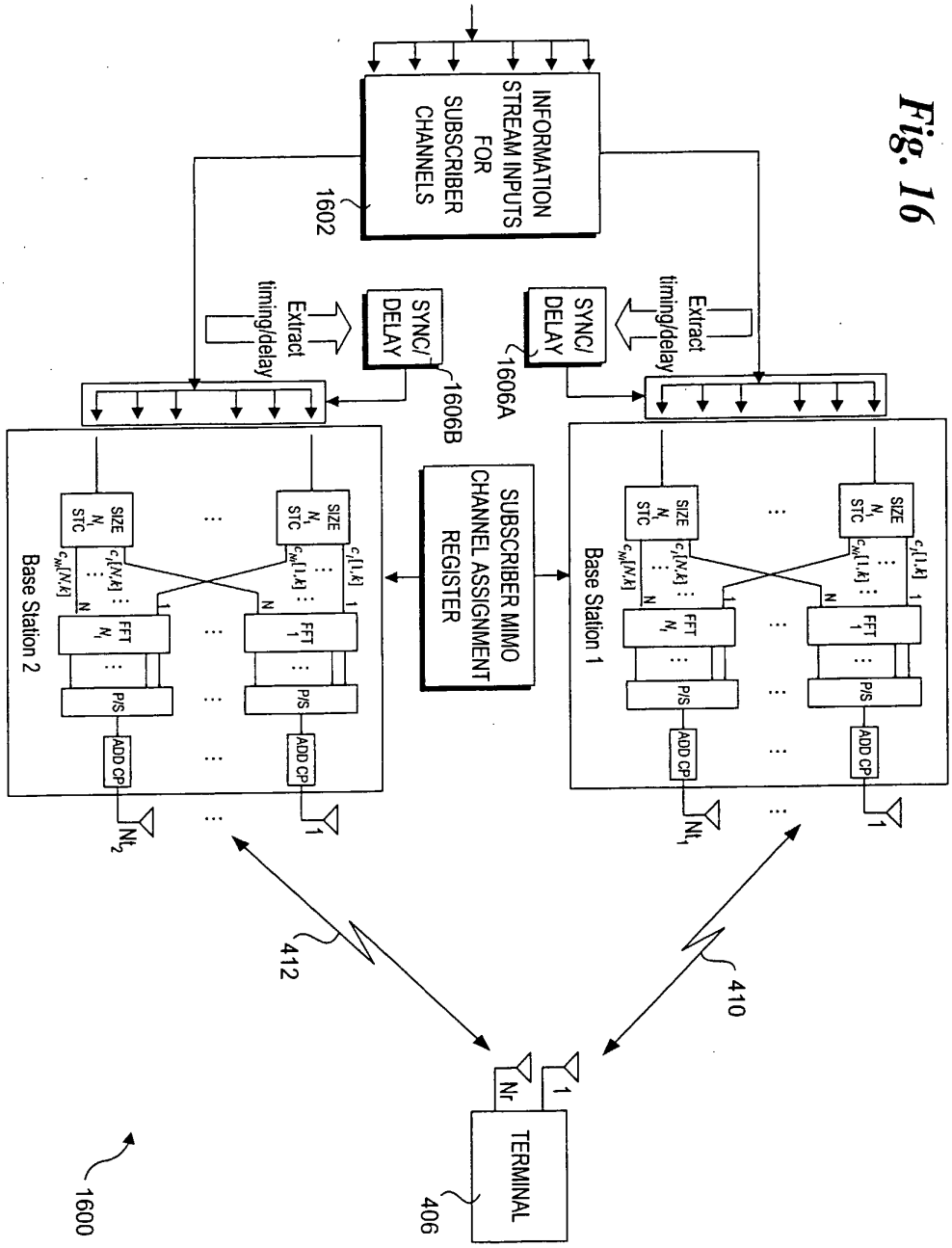

INFORMATION STREAM INPUTS FOR SUBSCRIBER CHANNELS
1602
SYNC/ DELAY
1606A
Extract timing/delay
SYNC/ DELAY
1606B
Extract timing/delay
SUBSCRIBER MIMO CHANNEL ASSIGNMENT REGISTER
Base Station 1
Base Station 2
SIZE
FFT
P/S
ADD CP
412
410
TERMINAL
406
1600

Fig. 16

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/176,298	07/05/2011	Paul Howard	9010-99460-US

CONFIRMATION NO. 4342

3624
VOLPE AND KOENIG, P.C.
UNITED PLAZA
30 SOUTH 17TH STREET
PHILADELPHIA, PA 19103

POA ACCEPTANCE LETTER

OC000000055556484

Date Mailed: 07/26/2012

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 07/18/2012.

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

/sleutchit/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/176,298	07/05/2011	Paul Howard	9010-99460-US

CONFIRMATION NO. 4342

22242
FITCH EVEN TABIN & FLANNERY, LLP
120 SOUTH LASALLE STREET
SUITE 1600
CHICAGO, IL 60603-3406

POWER OF ATTORNEY NOTICE

OC000000055556459

Date Mailed: 07/26/2012

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 07/18/2012.

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

/sleutchit/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/176,298	Filing Date 07/05/2011	☐ To be Mailed

APPLICATION AS FILED – PART I

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

APPLICATION AS AMENDED – PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	01/18/2013	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 38	Minus	** 20	= 18	X $ =		OR	X $62=	1116
	Independent (37 CFR 1.16(h))	* 6	Minus	***3	= 3	X $ =		OR	X $250=	750
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	**1866**

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

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/ANGELA s. WHITE/

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

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:	
Paul Howard	
Application No.: 13/176,298	Our File: IPW2-USCN191712
Confirmation No.: 4342	Date: January 19, 2013
Filed: July 5, 2011	
For: FEEDBACK CONTROL IN AN FDD TDD-CDMA SYSTEM	
Group: 2476	
Examiner: Ronald Abelson	

SUPPLEMENTAL PRELIMINARY AMENDMENT

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

Prior to examination, please amend the application as follows:

IN THE SPECIFICATION

Please replace paragraph [0034], [0047], [0048], and [0051] with the following amended paragraphs:

[0034] FIG. 3 illustrates an example where fractionation is employed. The UL-Beacon and PLCCH timeslots are active in every frame at the base station 302. However, terminal 304, terminal 306, and terminal 308 have been assigned a different fractionation phase. FIG. 3 illustrates the case where the fractionation phase is 3. For example, the fractionation phase of terminal 304 occurs in frame #O 310, the fractionation phase of terminal 306 occurs in frame #1 312, and the fractionation phase of terminal 308 occurs in frame #2 <u>314</u>. Since the fractionation phase is 3, the phase for terminal 304 occurs again in frame #3 316.

[0047] The computing system 500 may also include information storage system 510, which may include, for example, a media drive 512 and a removable storage interface 520. The media drive 512 may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a CD or DVD drive (R or RW), or other removable or fixed media drive. Storage media 518, may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive [[514]] <u>512</u>. As

these examples illustrate, the storage media 518 may include a computer-readable storage medium having stored therein particular computer software or data.

[0048] In alternative embodiments, information storage system 510 may include other similar components for allowing computer programs or other instructions or data to be loaded into computing system 500. Such components may include, for example, a removable storage unit 522 and an interface 520, such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units 522 and interfaces 520 that *u* allow software and data to be transferred from the removable storage unit [[518]] 522 to computing system 500.

[0051] In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system 500 using, for example, removable storage drive [[514]] 522, drive 512 or communications interface 524. The control logic (in this example, software instructions or computer program code), when executed by the processor 504, causes the processor 504 to perform the functions of the invention as described herein.

Please change the title to:

~~Feedback Control in an FDD TDD-CDMA System~~ Communications in a Wireless Network

IN THE DRAWINGS

The attached sheets of formal drawings replace the current sheets. These sheets, which include Figs. 1, 2, 3, 4, and 5, replace the original sheets including Figs. 1, 2, 3, 4, and 5. No new matter is added by the formal drawings.

IN THE CLAIMS

1. - 44. (CANCELED)

45. (NEW) A user equipment (UE) comprising:

a processor configured to receive resource allocation information associated with an uplink physical control channel, wherein the uplink physical control channel and a physical uplink shared channel have different resources;

the processor is further configured to send data over the physical uplink shared channel in assigned time intervals; and

the processor is further configured, in a time interval that it is not sending data over the physical uplink shared channel, to send a signal over the uplink physical control channel based on the received resource allocation information.

46. (NEW) The UE of claim 45 wherein the processor is further configured to feedback information from a downlink control channel.

47. (NEW) The UE of claim 46 wherein the processor is further configured to receive data on a physical downlink shared channel.

48. (NEW) The UE of claim 47 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

49. (NEW) The UE of claim 46 wherein the feedback information includes power control information.

50. (NEW) The UE of claim 49 wherein the downlink control channel includes power control information for a plurality of UEs using different bits.

51. (NEW) The UE of claim 45 wherein in the time interval that the uplink physical control channel is sent, a plurality of UEs transmit on uplink physical control channels in that time interval.

52. (NEW) A network device comprising:

a processor configured to send resource allocation information associated with an uplink physical control channel, wherein the uplink physical control channel and a physical uplink shared channel have different resources;

the processor is further configured to receive data over the physical uplink shared channel in assigned time intervals; and

the processor is further configured, in a time interval that it is not receiving data over the physical uplink shared channel, to receive a signal over the uplink physical control channel based on the sent resource allocation information.

53. (NEW) The network device of claim 52 wherein the processor is further configured to feedback information on a downlink control channel.

54. (NEW) The network device of claim 53 wherein the processor is further configured to send data on a physical downlink shared channel.

55. (NEW) The network device of claim 54 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

56. (NEW) The network device of claim 53 wherein the feedback information includes power control information.

57. (NEW) The network device of claim 56 wherein the downlink control channel includes power control information for a plurality of UEs using different bits.

58. (NEW) The network device of claim 53 wherein in the time interval that the uplink physical control channel is received, a plurality of UEs transmit on uplink physical control channels in that time interval.

59. (NEW) A wireless network comprising:

a network device comprising:

circuitry configured to send resource allocation information associated with an uplink physical control channel, wherein the uplink physical control channel and a physical uplink shared channel have different resources;

and

a user equipment (UE) comprising:

circuitry configured to send data over the physical uplink shared channel in assigned time intervals; and

the circuitry is further configured, in a time interval that it is not sending data over the physical uplink shared channel, to send a signal over the uplink physical control channel based on the sent resource allocation information.

60. (NEW) The wireless network of claim 59 wherein the UE receives feedback information on a downlink control channel.

61. (NEW) The wireless network of claim 60 wherein the network device is

configured to send data on a physical downlink shared channel.

62. (NEW) The wireless network of claim 61 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

63. (NEW) The wireless network of claim 60 wherein the feedback information includes power control information.

64. (NEW) The wireless network of claim 63 wherein the network device is configured to send, on the downlink control channel, power control information for a plurality of UEs using different bits.

65. (NEW) The wireless network of claim 60 wherein in the time interval that the signal is sent on the uplink physical control channel by the UE, a plurality of UEs transmit on uplink physical control channels in that time interval.

66. (NEW) A method performed by a user equipment (UE), the method comprising:

receiving, by the UE, resource allocation information associated with an uplink physical control channel, wherein the uplink physical control channel and a

physical uplink shared channel have different resources;

sending, by the UE, data over the physical uplink shared channel in assigned time intervals; and

sending, by the UE in a time interval that it is not sending data over the physical uplink shared channel, a signal over the uplink physical control channel based on the received resource allocation information.

67. (NEW) The method of claim 66 further comprising:

receiving, by the UE, feedback information from a downlink control channel.

68. (NEW) The method of claim 67 further comprising:

receiving, by the UE, data on a physical downlink shared channel.

69. (NEW) The method of claim 68 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

70. (NEW) The method of claim 67 wherein the feedback information includes power control information.

71. (NEW) The method of claim 70 wherein the downlink control channel

includes power control information for a plurality of UEs using different bits.

72. (NEW) The method of claim 66 wherein in the time interval that the uplink physical control channel is sent, a plurality of UEs transmit on uplink physical control channels in that time interval.

73. (NEW) A method performed by a network device, the method comprising:

sending, by the network device, resource allocation information associated with an uplink physical control channel, wherein the uplink physical control channel and a physical uplink shared channel have different resources;

receiving, by the network device, data over the physical uplink shared channel in assigned time intervals; and

receiving, by the network device in a time interval that it is not receiving data over the physical uplink shared channel, a signal over the uplink physical control channel based on the sent resource allocation information.

74. (NEW) The method of claim 73 further comprising:

sending, by the network device, feedback information on a downlink control channel.

75. (NEW) The method of claim 74 further comprising:

sending, by the network device, data on a physical downlink shared channel.

76. (NEW) The method of claim 75 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

77. (NEW) The method of claim 74 wherein the feedback information includes power control information.

78. (NEW) The method of claim 77 wherein the downlink control channel includes power control information for a plurality of UEs using different bits.

79. (NEW) The method of claim 74 wherein in the time interval that the uplink physical control channel is received, a plurality of UEs transmit on uplink physical control channels in that time interval.

80. (NEW) A method performed by a wireless network, the method comprising:

sending, by a network device, resource allocation information associated with

an uplink physical control channel, wherein the uplink physical control channel and a physical uplink shared channel have different resources;

sending, by a user equipment (UE), data over the physical uplink shared channel in assigned time intervals; and

sending, by the UE in a time interval that it is not sending data over the physical uplink shared channel, a signal over the uplink physical control channel based on the sent resource allocation information.

81. (NEW) The method of claim 80 further comprising:

receiving, by the UE, feedback information on a downlink control channel.

82. (NEW) The method of claim 81 further comprising:

sending, by the network device, data on a physical downlink shared channel.

83. (NEW) The method of claim 82 wherein the downlink control channel and the physical downlink shared channel are time multiplexed.

84. (NEW) The method of claim 81 wherein the feedback information includes power control information.

85. (NEW) The method of claim 84 further comprising:

sending, by the network device on the downlink control channel, power control information for a plurality of UEs using different bits.

86. (NEW) The method of claim 81 wherein in the time interval that the signal is sent on the uplink physical control channel by the UE, a plurality of UEs transmit on uplink physical control channels in that time interval.

REMARKS

In the specification, paragraph [0034] is amended to include a missing reference number. Paragraph [0047] corrects a typographical error by changing media drive 514 to media drive 512. Paragraph [0048] corrects a typographical error where removable storage unit 518 is changed to removable storage unit 522. Paragraph [0051] corrects a typographical error as removable storage drive 514 is changed to removable storage drive 522. Support for these changes may be found at least in the drawings. No new matter is added by any of these amendments. Also, a new title is submitted herewith.

Early consideration and allowance of the pending claims is respectfully requested.

Respectfully submitted,

Paul Howard

By /Harry Vartanian/
Harry Vartanian
Registration No. 56,787
(215) 568-6400

Volpe and Koenig, P.C.
United Plaza
30 South 17th Street
Philadelphia, PA 19103-4009

HV/aw

Electronic Patent Application Fee Transmittal

Application Number:	13176298
Filing Date:	05-Jul-2011
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Filer:	Harry Vartanian
Attorney Docket Number:	IPW2-USCN191712

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Claims in excess of 20	1202	18	62	1116
Independent claims in excess of 3	1201	3	250	750
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1866**

Electronic Acknowledgement Receipt	
EFS ID:	14743509
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	3624
Filer:	Harry Vartanian
Filer Authorized By:	
Attorney Docket Number:	IPW2-USCN191712
Receipt Date:	19-JAN-2013
Filing Date:	05-JUL-2011
Time Stamp:	16:10:51
Application Type:	Utility under 35 USC 111(a)

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1	Drawings-only black and white line drawings	IPW2_USCN191712_Formal_Drawings.PDF	496578 1bf102b896726c98a1dd55131f0e4ef91a9f1ec6	no	5
Warnings:					
Information:					
2		IPW2_USCN191712_Preliminary_Amendment.pdf	74218 c94922bf7d012bc126a61d0c9f13579d9b50c53c	yes	16
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Preliminary Amendment		1	1	
	Specification		2	4	
	Drawings-only black and white line drawings		5	5	
	Claims		6	15	
	Applicant Arguments/Remarks Made in an Amendment		16	16	
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	31864 6d6c60cb88a3c9d97bbc741f8da8b97ae3d86b04	no	2
Warnings:					
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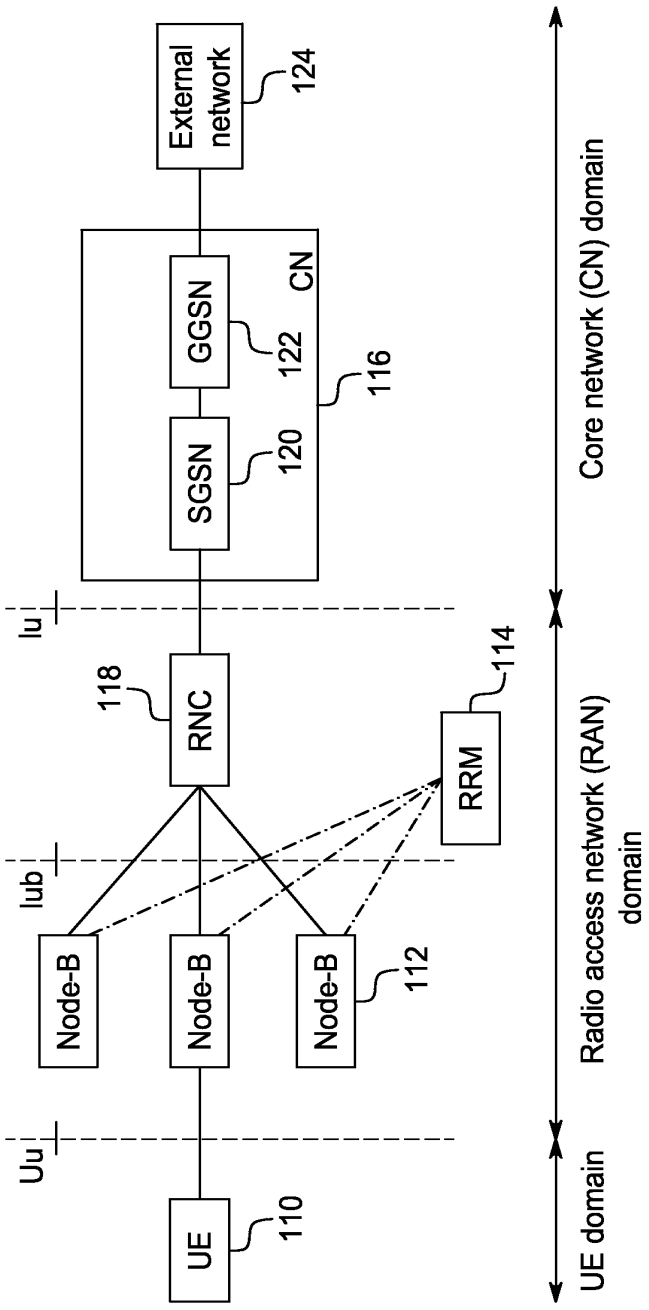

External network
124
GGSN
122
CN
116
SGSN
120
Core network (CN) domain
Iu
118
RNC
114
RRM
Iub
Node-B
Node-B
Node-B
112
Radio access network (RAN) domain
Uu
UE
110
UE domain

FIG. 1

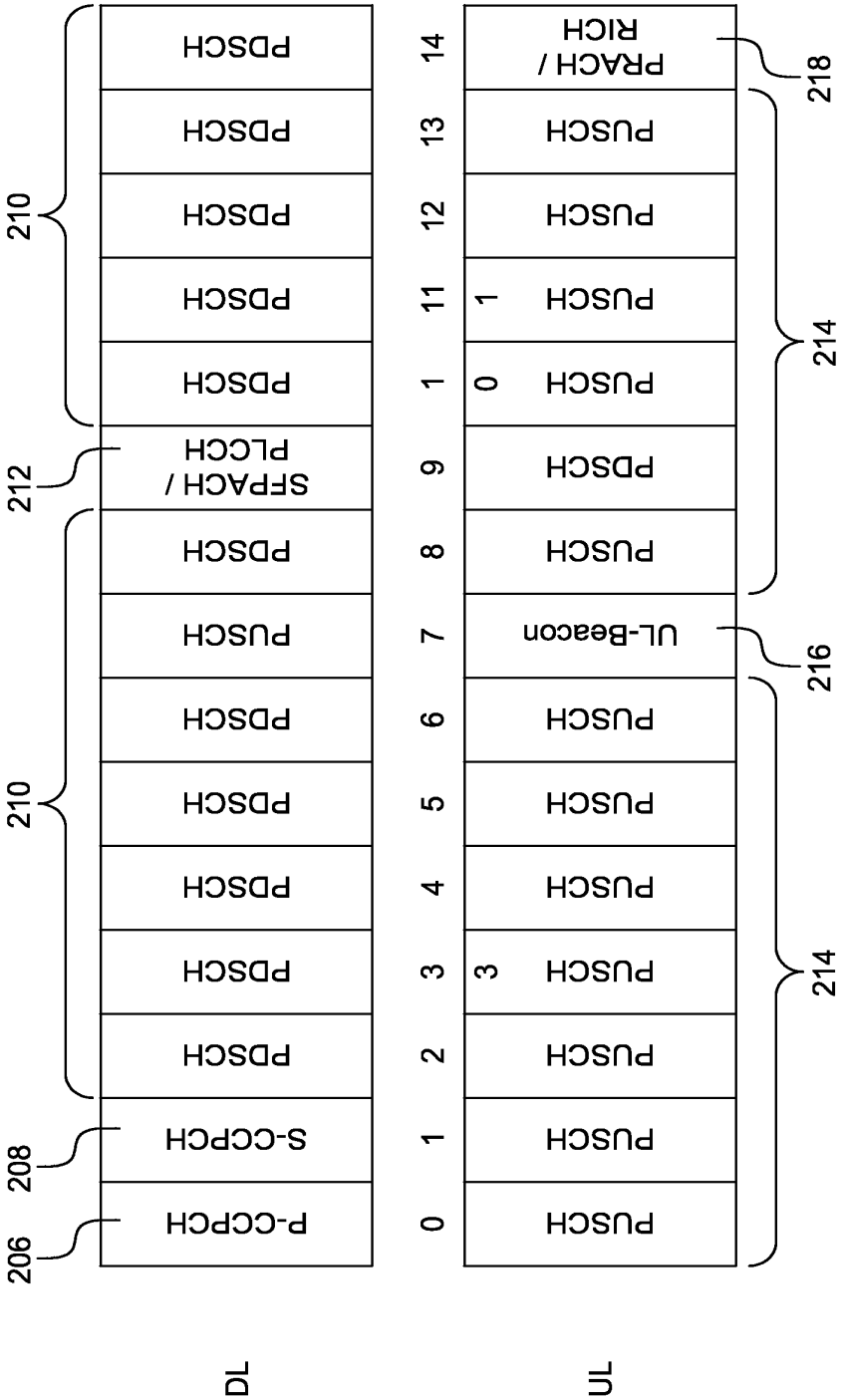

DL
UL
P-CCPCH
S-CCPCH
PDSCH
SFPACH / PLCCH
PUSCH
UL-Beacon
PRACH / RICH
206
208
210
212
214
216
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2
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4
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6
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11
12
13
14

FIG. 2

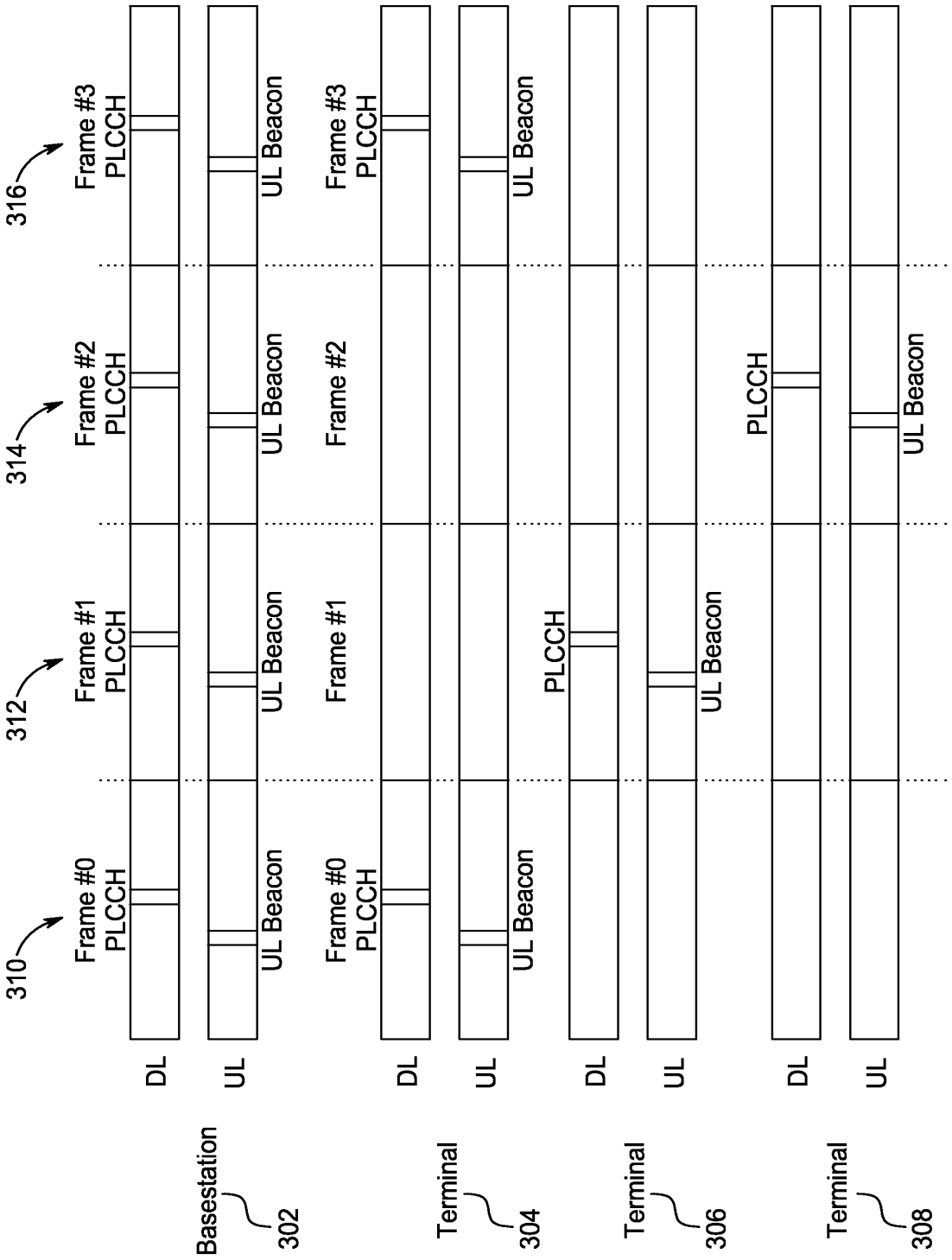

310
312
314
316
Frame #0 PLCCH
Frame #1 PLCCH
Frame #2 PLCCH
Frame #3 PLCCH
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PLCCH
DL
UL
Basestation 302
Terminal 304
Terminal 306
Terminal 308

FIG. 3

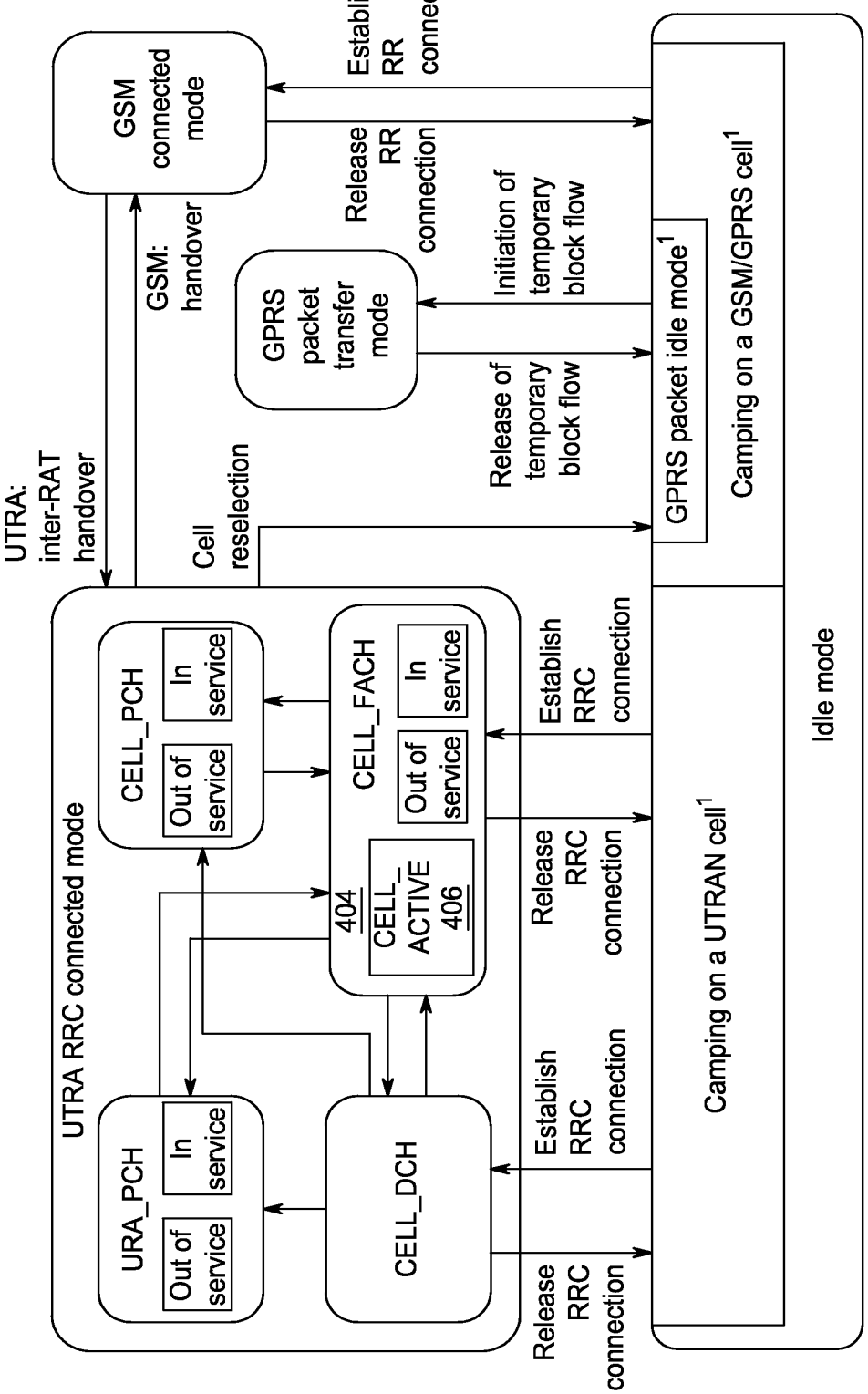

UTRA:
inter-RAT
handover
GSM:
handover
Cell
reselection
GSM
connected
mode
GPRS
packet
transfer
mode
Establish
RR
connection
Release
RR
connection
Initiation of
temporary
block flow
Release of
temporary
block flow
GPRS packet idle mode[1]
Camping on a GSM/GPRS cell[1]
UTRA RRC connected mode
CELL_PCH
In
service
Out of
service
CELL_FACH
In
service
Out of
service
404
CELL_
ACTIVE
406
URA_PCH
In
service
Out of
service
CELL_DCH
Establish
RRC
connection
Release
RRC
connection
Establish
RRC
connection
Release
RRC
connection
Camping on a UTRAN cell[1]
Idle mode

FIG. 4

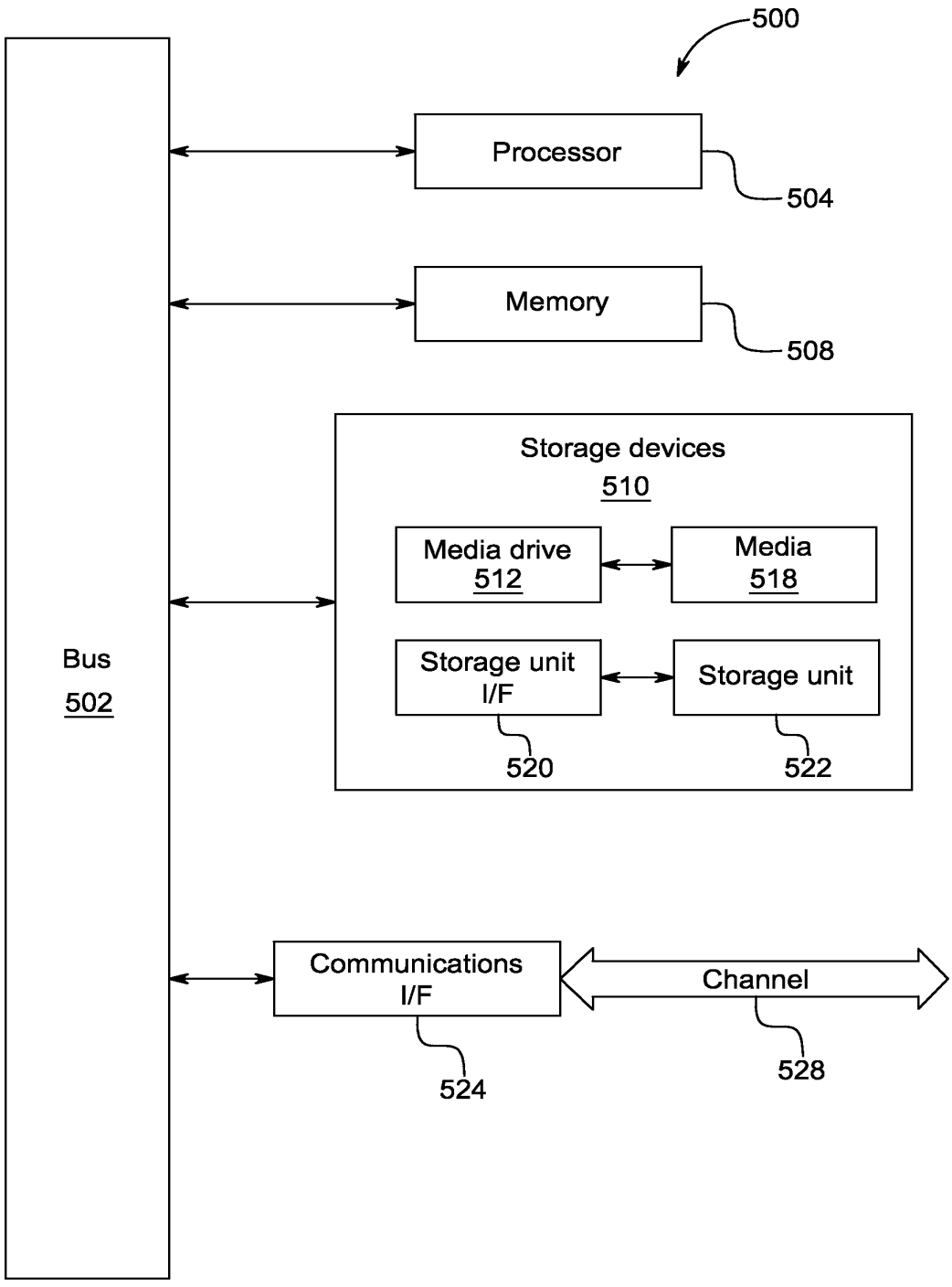

500
Processor
504
Memory
508
Storage devices
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Media
518
Storage unit
I/F
Storage unit
520
522
Bus
502
Communications
I/F
Channel
524
528

FIG. 5

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
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	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2476
	Examiner Name	Ronald B. Abelson
	Attorney Docket Number	IPW2-USCN191712

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	1	6611509	BA	2003-08-26	Hayashi et al.	* Corresponds to JP 11-261544
	2	8072916	BB	2011-12-06	Dateki	* Corresponds to JP 2006-197318

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	1	11-261544	JP		1999-09-24	Hayashi et al.		☐
	2	2006-197318	JP		2011-12-06	Dateki		☐

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2476
	Examiner Name	Ronald B. Abelson
	Attorney Docket Number	IPW2-USCN191712

	3	06019263	WO	A2	2006-02-23	Chun		☐

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	1	OFFICE ACTION, Japanese Patent Application No. 2009-543459, dated December 18, 2012.	☐

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13176298
	Filing Date	2011-07-05
	First Named Inventor	Paul Howard
	Art Unit	2476
	Examiner Name	Ronald B. Abelson
	Attorney Docket Number	IPW2-USCN191712

CERTIFICATION STATEMENT

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

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

OR

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

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

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

Signature	/Harry Vartanian/	Date (YYYY-MM-DD)	2013-02-07
Name/Print	Harry Vartanian	Registration Number	56,787

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8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PATENT ABSTRACTS OF JAPAN

(11)Publication number : **11-261544**
(43)Date of publication of application : **24.09.1999**

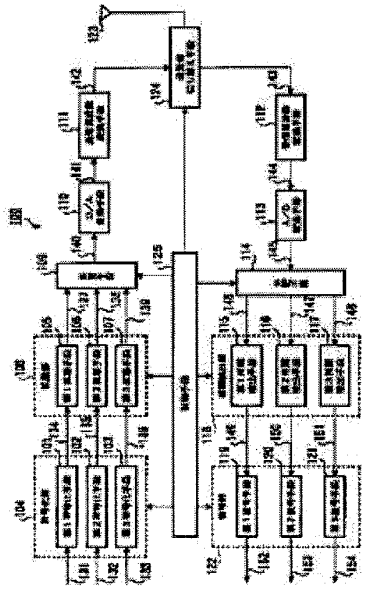
(51)Int.Cl. **H04L 5/16**
H04Q 7/36
H04J 3/00
H04J 3/06
H04J 3/22
H04B 1/707
H04L 12/28

(21)Application number : **10-078317**
(22)Date of filing : **10.03.1998**

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(54) **SYSTEM AND METHOD FOR TIME DIVISION DUPLEX CDMA MOBILE COMMUNICATION**

(57)Abstract:
PROBLEM TO BE SOLVED: To allow a mobile station to reduce an acquisition time of synchronization with a base station even when time slot allocation of up and down lines is changed in accordance with information quantities when information quantities of the up and down lines are asymmetrical and also to effectively perform open loop transmission power control.
SOLUTION: A fixed down line time slot is allocated at a prescribed interval to a time slot divided into plural parts in a communication frame through a controlling means 125 of a base station 10 in a time division duplex CDMA mobile communication system; time slots of down and up lines are divided in accordance with the ratio of total information quantities of the down and up lines in the system and allocated to time slots other than the above, a control channel signal including a control channel for synchronization is transmitted in the fixed down line time slot and communication channel signals of the down and up lines are transmitted in time slots of necessary quantity of the down and up lines in accordance with information quantity.



(19)日本国特許庁（ＪＰ）　(12) **公開特許公報（Ａ）**　(11)特許出願公開番号

特開平11－261544

(43)公開日　平成11年(1999)９月24日

(51)Int.Cl.[6]		識別記号	ＦＩ		
Ｈ０４Ｌ	5/16		Ｈ０４Ｌ	5/16	
Ｈ０４Ｑ	7/36		Ｈ０４Ｊ	3/00	Ｈ
Ｈ０４Ｊ	3/00			3/06	Ｚ
	3/06			3/22	
	3/22		Ｈ０４Ｂ	7/26	１０５Ｄ

審査請求　未請求　請求項の数21　ＦＤ　（全 17 頁）　最終頁に続く

(21)出願番号　特願平10－78317

(22)出願日　平成10年(1998)３月10日

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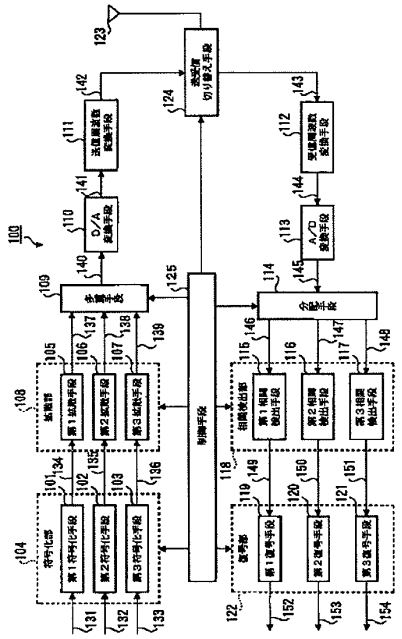
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(54)【発明の名称】　時分割複信ＣＤＭＡ移動体通信システム及びその方法

(57)【要約】

【課題】　上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても移動局における基地局との同期の獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができるようにすること。

【解決手段】　時分割複信ＣＤＭＡ移動体通信システムにおける基地局１００の制御手段１２５の制御によって、通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当て、それ以外のタイムスロットに、システム内の下りと上り回線の総情報量の比に応じて下り回線と上り回線のタイムスロットを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を固定下り回線タイムスロットで伝送し、下りと上り回線の通信チャネル信号を情報量に応じて必要な数量の下り回線と上り回線のタイムスロットで伝送する構成とした。



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【特許請求の範囲】

【請求項１】　通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回線と上り回線の通信チャネル信号を情報量に応じて必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送する制御手段を有する基地局装置、を具備することを特徴とする時分割複信ＣＤＭＡ移動体通信システム。

【請求項２】　制御手段が、所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てることを特徴とする請求項１記載の時分割複信ＣＤＭＡ移動体通信システム。

【請求項３】　所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局装置との同期を確立する制御手段を有する移動局装置、を具備することを特徴とする時分割複信ＣＤＭＡ移動体通信システム。

【請求項４】　制御手段が、所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分することを特徴とする請求項３記載の時分割複信ＣＤＭＡ移動体通信システム。

【請求項５】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信システム。

【請求項６】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信システム。

【請求項７】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信システム。

【請求項８】　通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回線と上り回線の通信チャネル信号を情報量に応じて必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送する制御手段を、を具備することを特徴とする基地局装置。

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【請求項９】　制御手段が、所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てることを特徴とする請求項８記載の基地局装置。

【請求項１０】　所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局装置との同期を確立する制御手段、を具備することを特徴とする移動局装置。

【請求項１１】　制御手段が、所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分することを特徴とする請求項１０記載の移動局装置。

【請求項１２】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項１０又は請求項１１記載の移動局装置。

【請求項１３】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項１０又は請求項１１記載の移動局装置。

【請求項１４】　制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項１０又は請求項１１記載の移動局装置。

【請求項１５】　基地局にあって、通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回

線と上り回線の通信チャネル信号を情報量に応じて必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送することを特徴とする時分割複信ＣＤＭＡ移動体通信方法。

【請求項１６】　所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てることを特徴とする請求項１５記載の時分割複信ＣＤＭＡ移動体通信方法。

【請求項１７】　移動局にあって、所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局との同期を確立することを特徴とする時分割複信ＣＤＭＡ移動体通信方法。

【請求項１８】　所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分することを特徴とする請求項１７記載の時分割複信ＣＤＭＡ移動体通信方法。

【請求項１９】　所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信方法。

【請求項２０】　所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項１７又は請求項１８記載の時分割複信ＣＤＭＡ移動体通信方法。

【請求項２１】　所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うことを特徴とする請求項１７又は請求項１８記載の時分割複信ＣＤＭＡ移動体通信方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は同一の無線周波数を時間分割して上り回線と下り回線を交互に通信する送受信同一帯域方式を適用した時分割複信ＣＤＭＡ移動体通信システム及びその方法に関する。

【０００２】

【従来の技術】従来、ＣＤＭＡ（Code Division Multiple Access：符号分割多元接続）を用いた移動体通信システムとして、Ｗ－ＣＤＭＡ方式が知られている。Ｗ－ＣＤＭＡ方式は、複信方式としてはＦＤＤ(Frequency Division Duplex：周波数分割複信)方式を用いている。

【０００３】複信方式には、この他にＴＤＤ(Time Division Duplex：時分割複信方式)が知られている。ＴＤＤは、送受信同一帯域方式であり、ピンポン方式とも呼ばれ、同一の無線周波数を時間分割して上り回線と下り回線を交互に通信する方式である。

【０００４】また、多元接続方式とは、同一の帯域で複数の局が同時に通信を行う際の回線接続方式のことである。ＣＤＭＡとは、情報信号のスペクトルを、情報を拡散符号で拡散して広い帯域で伝送するスペクトル拡散通信によって多元接続を行う技術である。直接拡散方式とは、拡散において拡散符号を情報信号に乗じる方式である。

【０００５】即ち、直接拡散ＣＤＭＡでは、複数の通信回線が同一の周波数を共有するため受信端でのそれぞれの通信波の強さを同一にする問題（遠近問題）があり、この克服がＣＤＭＡ通信システム実現の前提になる。

【０００６】遠近問題は、異なる位置にいる多数移動局（移動無線端末装置）からの電波を同時に受信する基地局受信で厳しくなり、このため移動局側では各伝送路の状態に応じた送信電力制御が必須である。

【０００７】ＴＤＤ方式においては、上下回線の周波数帯域が同一であることからフェージングなど伝搬路の状態について、上下回線の間隔が十分に小さければ高い相関性があり、これを利用してオープンループ制御による送信電力制御が可能である。

【０００８】このようなＣＤＭＡ移動体通信システムにおいて、通信フレームを複数のタイムスロットに時間的に分割して、通信チャネルや制御チャネルの各々にタイムスロットを割り当てて複数回線の通信を行う時分割多重の構成を備えるものがある。

【０００９】図８は、従来の時分割複信ＣＤＭＡ移動体通信システムにおけるフレーム図を示す。

【００１０】この図８に示すように、１フレーム８０１を８個のタイムスロット０～７に分割して、タイムスロット０～３を下り回線、タイムスロット４～７を上り回線とする例である。

【００１１】基地局（図示せず）から移動局（図示せず）へ向かう下り回線８０２には、同期用制御チャネルなどの共通制御チャネル８０３や、基地局と個別の移動局との間の個別制御チャネルとユーザー情報チャネル８０４が多重され、移動局から基地局へ向かう上り回線８０５には、個別制御チャネルとユーザー情報チャネル８０６が多重されている。

【００１２】移動局は、電源投入時に、下り回線８０２の共通制御チャネル８０３の同期用制御チャネルを検出することにより受信して、基地局との同期を獲得する。その後、個別制御チャネルを介して回線接続を行い、ユーザー情報チャネル８０４による通信を開始する。ここ

で、割り当てられた下り回線タイムスロットの受信品質を測定し、この測定結果に基づいて、割り当てられた上り回線タイムスロットの送信電力制御を行う。

【００１３】

【発明が解決しようとする課題】しかし、上記従来の時分割複信ＣＤＭＡ移動体通信システムにおいては、上下回線の情報量に応じて、上り回線と下り回線のタイムスロットの割り当てを変えると、同期用制御チャネルの構成が不規則となり、移動局が電源投入時に基地局との同期を獲得するまでの時間が長くなる。

【００１４】また、各通信回線について、割り当てられた下り回線タイムスロットと上り回線タイムスロットの間隔が大きいため、上下回線の伝搬路状態の相関が低くなりオープンループ制御の送信電力制御の効果が低下していた。本発明は、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても移動局における基地局との同期の獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる時分割複信ＣＤＭＡ移動体通信システム及びその方法を提供することを目的とする。

【００１５】

【課題を解決するための手段】本発明は、上記課題を解決するため、以下の構成とした。

【００１６】請求項１記載の時分割複信ＣＤＭＡ移動体通信システムは、通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回線と上り回線の通信チャネル信号を情報量に応じて必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送する制御手段を有する基地局装置、を具備する構成とした。

【００１７】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００１８】また、請求項２記載の時分割複信ＣＤＭＡ移動体通信システムは、請求項１記載の時分割複信ＣＤＭＡ移動体通信システムにおいて、制御手段が、所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てる構成とした。

【００１９】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００２０】また、請求項３記載の時分割複信ＣＤＭＡ移動体通信システムは、所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局装置との同期を確立する制御手段、を具備する構成とした。

【００２１】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００２２】また、請求項４記載の時分割複信ＣＤＭＡ移動体通信システムは、請求項３記載の時分割複信ＣＤＭＡ移動体通信システムにおいて、制御手段が、所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分する構成とした。

【００２３】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００２４】また、請求項５記載の時分割複信ＣＤＭＡ移動体通信システムは、請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信システムにおいて、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００２５】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００２６】また、請求項６記載の時分割複信ＣＤＭＡ移動体通信システムは、請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信システムにおいて、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００２７】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００２８】また、請求項７記載の時分割複信ＣＤＭＡ移動体通信システムは、請求項３又は請求項４記載の時

分割複信ＣＤＭＡ移動体通信システムにおいて、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００２９】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００３０】また、請求項８記載の基地局装置は、通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回線と上り回線の通信チャネル信号を情報量に応じて必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送する制御手段を、を具備する構成とした。

【００３１】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００３２】また、請求項９記載の基地局装置は、請求項８記載の基地局装置において、制御手段が、所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てる構成とした。

【００３３】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００３４】また、請求項１０記載の移動局装置は、所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局装置との同期を確立する制御手段、を具備する構成とした。

【００３５】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００３６】また、請求項１１記載の移動局装置は、請求項１０記載の移動局装置において、制御手段が、所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分する構成とした。

【００３７】この構成により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００３８】また、請求項１２記載の移動局装置は、請求項１０又は請求項１１記載の移動局装置において、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００３９】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００４０】また、請求項１３記載の移動局装置は、請求項１０又は請求項１１記載の移動局装置において、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００４１】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００４２】また、請求項１４記載の移動局装置は、請求項１０又は請求項１１記載の移動局装置において、制御手段が、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行う構成とした。

【００４３】この構成により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００４４】また、請求項１５記載の時分割複信ＣＤＭＡ移動体通信方法は、基地局にあって、通信フレーム内の複数に分割されるタイムスロットに、所定間隔で固定下り回線タイムスロットを割り当てると共に、前記固定下り回線タイムスロット以外のタイムスロットに、システム内の下り回線と上り回線の総情報量の比に応じて下り回線タイムスロットと上り回線タイムスロットとを分配して割り当て、同期用制御チャネルを含む制御チャネル信号を前記固定下り回線タイムスロットで伝送し、下り回線と上り回線の通信チャネル信号を情報量に応じて

必要な数量の前記下り回線タイムスロットと前記上り回線タイムスロットで伝送するようにした。

【００４５】この方法により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００４６】また、請求項１６記載の時分割複信ＣＤＭＡ移動体通信方法は、請求項１５記載の時分割複信ＣＤＭＡ移動体通信方法において、所定間隔で固定下り回線タイムスロットを割り当てる際に、１つ置きに割り当てるようにした。

【００４７】この方法により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局装置における基地局装置との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００４８】また、請求項１７記載の時分割複信ＣＤＭＡ移動体通信方法は、移動局にあって、所定間隔で固定下り回線タイムスロットが割り当てられた通信フレームによる受信信号と、前記固定下り回線タイムスロットで伝送される同期用制御チャネル信号の拡散符号との相関値を、所定タイムスロット間隔で積分して前記同期用制御チャネルを検出することにより基地局との同期を確立するようにした。

【００４９】この方法により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００５０】また、請求項１８記載の時分割複信ＣＤＭＡ移動体通信方法は、請求項１７記載の時分割複信ＣＤＭＡ移動体通信方法において、所定タイムスロット間隔で積分する際に、２タイムスロット長間隔で積分するようにした。

【００５１】この方法により、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局装置において基地局装置との同期を確立することができる。

【００５２】また、請求項１９記載の時分割複信ＣＤＭＡ移動体通信方法は、請求項３又は請求項４記載の時分割複信ＣＤＭＡ移動体通信方法において、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うようにした。

【００５３】この方法により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００５４】また、請求項２０記載の時分割複信ＣＤＭＡ移動体通信方法は、請求項１７又は請求項１８記載の時分割複信ＣＤＭＡ移動体通信方法において、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネルの受信品質と、自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルの受信品質とを測定し、これら測定受信品質に基づいて上り回線の送信電力制御を行うようにした。

【００５５】この方法により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００５６】また、請求項２１記載の時分割複信ＣＤＭＡ移動体通信方法は、請求項１７又は請求項１８記載の時分割複信ＣＤＭＡ移動体通信方法において、所定タイムスロット間隔で配置された同期用制御チャネルを含む制御チャネル、又は自局に割り当てられた下り回線タイムスロットにおけるユーザー情報チャネルを切り替えて受信品質を測定し、この測定受信品質に基づいて上り回線の送信電力制御を行うようにした。

【００５７】この方法により、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【００５８】

【発明の実施の形態】以下、本発明の時分割複信ＣＤＭＡ移動体通信システム及びその方法の実施の形態を図面を用いて具体的に説明する。

【００５９】（実施の形態１）図１は、本発明の実施の形態１に係る時分割複信ＣＤＭＡ移動体通信システムにおける基地局のブロック図を示す。

【００６０】この図１に示す基地局１００は、第１符号化手段１０１、第２符号化手段１０２及び第３符号化手段１０３を有する符号化部１０４と、第１拡散手段１０５、第２拡散手段１０６及び第３拡散手段１０７を有する拡散部１０８と、多重手段１０９と、Ｄ／Ａ変換手段１１０と、送信周波数変換手段１１１と、受信周波数変換手段１１２と、Ａ／Ｄ変換手段１１３と、分配手段１１４と、第１相関検出手段１１５、第２相関検出手段１１６及び第３相関検出手段１１７を有する相関検出部１１８と、第１復号手段１１９、第２復号手段１２０及び第３復号手段１２１を有する復号部１２２と、送受信アンテナ１２３と、送受信切り替え手段１２４と、制御手段１２５とを備えて構成されている。

【００６１】各符号化手段１０１～１０３は、第１～第３下り回線個別制御チャネル信号１３１，１３２，１３３の符号化を行うものであり、各拡散手段１０５～１０７は、その符号化によって得られる各チャネルの符号化信号１３４，１３５，１３６の拡散を行うものである。

【００６２】多重手段１０９は、その拡散によって得られる各チャネルの拡散信号１３７，１３８，１３８を多

重するものであり、D／A変換手段１１０は、その多重信号１４０をアナログ信号１４１に変換するものであり、送信周波数変換手段１１１は、アナログ信号１４１を無線周波数の送信信号１４２に変換するものである。

【００６３】送受信切り替え手段１２４は、送受信アンテナ１２３を送信側と受信側に切り替えて接続するものであり、上記送信信号１４２は送受信切り替え手段１２４を介して送受信アンテナ１２３から図示せぬ移動局へ無線送信されるようになっている。

【００６４】受信周波数変換手段１１２は、送受信アンテナ１２３で受信され、送受信切り替え手段１２４を介して送られてきた無線周波数の受信信号４３１をベースバンド周波数の信号１４４に変換するものである。

【００６５】A／D変換手段１１３は、そのベースバンド周波数の信号１４４をディジタル受信信号１４５に変換するものであり、分配手段１１４は、ディジタル信号に変換された受信信号１４５を各チャネル信号１４６，１４７，１４８に分配するものである。

【００６６】各相関検出手段１１５～１１７は、上り回線共通個別チャネル信号１４６～１４８の相関検出を行うものであり、各復号手段１１９～１２１は、その各チャネルの相関検出信号１４９，１５０，１５１の復号を行い、これら各チャネルの復号信号１５２，１５３，１５４を出力するものである。また、制御手段１２５は、前記した各手段の制御を行うものである。

【００６７】このような構成において、まず、同期用制御チャネルなどの下り回線共通チャネル信号１３１～１３３が、各符号化手段１０１～１０３で符号化され、更にフレーム組み立てされて、各拡散手段１０５～１０７へ出力される。但し、それらの符号化は誤り訂正符号化であってもよく、また、その場合にはインターリーブ処理も施される。

【００６８】各拡散手段１０５～１０７においては、拡散符号を用いて各チャネルの符号化信号１３４～１３６の周波数帯域が拡散され、この各拡散信号１３７～１３９が多重手段１０９へ出力される。但し、拡散符号は制御手段１２５から指示されるようにしてもよい。

【００６９】多重手段１０９においては、各拡散信号１３７～１３９が制御手段１２５の指示に応じてタイムスロットに配置されて時間多重される。この際、同一のタイムスロットに配置されたチャネルが加算多重される。但し、加算多重処理が行われる場合、それぞれのチャネルの拡散信号１３７～１３９毎にに振幅を制御する送信電力制御がなされるようにしてもよい。

【００７０】多重信号１４１においては、D／A変換手段１１０でディジタル信号からアナログ信号１４１に変換され、この変換された信号１４１が送信周波数変換手段１１１で無線周波数に周波数変換され、更にその周波数変換された送信信号１４２が送受信切り替え手段１２４を介して送受信アンテナ１２３から移動局へ送信される。

【００７１】ここで、送受信切り替え手段１２４は、制御手段１２５の指示に応じて送受信アンテナ１２３を、下り回線タイムスロットでは送信周波数変換手段１１１に接続し、上り回線タイムスロットでは受信周波数変換手段１１２に接続する。

【００７２】一方、送受信アンテナ１２３で受信された移動局からの信号は、送受信切り替え手段１２４を介して受信信号１４３として受信周波数変換手段１１２に入力され、ここで、ベースバンド周波数に変換される。

【００７３】ベースバンド周波数のアナログ信号１４４は、A／D変換手段１１３でディジタル信号１４５に変換され、分配手段１１４へ出力される。分配手段１１４においては、制御手段１２５の指示に応じて、ディジタル信号１４５が時間分離され、これによって得られた各上り共通制御チャネル信号１４６～１４８が各相関検出手段１１５～１１７へ出力される。

【００７４】各相関検出手段１１５～１１７においては、各上り共通制御チャネル信号１４６～１４８の逆拡散が行われ、受信された信号と拡散符号との相関値が検出される。このとき、それぞれの拡散符号は、制御手段１２５から指示されるようにしてもよい。

【００７５】検出された相関値（相関信号）１４９～１５１は、それぞれ各復号手段１１９～１２１へ出力され、ここで、相関値１４９～１５１に基づいた上り共通制御チャネル信号の復号が行われる。このとき、移動局で上り回線の誤り訂正符号化を行うのであれば、デインターリーブ処理を施して、誤り訂正復号を行う構成とする。

【００７６】また、各符号化手段１０１～１０３、各拡散手段１０５～１０７、各相関検出手段１１５～１１７、各復号手段１１９～１２１などは、各チャネル毎に設けなくても、時分割によって共通のものを使用してもよい。

【００７７】ここで、制御手段１２５が行う制御のうちタイムスロットの割り当て制御について、図２を参照して説明する。図２は時分割複信ＣＤＭＡ移動体通信システムにおける通信フレームのタイムスロットの割り当てを示すフレーム図であり、１フレーム２０１を１６個のタイムスロット０～１６に分割する例である。

【００７８】但し、図２において、凡例で代表して示す枠２０２は、下り回線共通制御チャネルと下り回線ユーザ情報チャネルが配置されるタイムスロットを示し、枠２０３は、下り回線ユーザ情報チャネルだけが配置されるタイムスロット、枠２０４は、上り回線チャネルが配置されるタイムスロットを示す。

【００７９】制御手段１２５は、まず、下り回線の情報量と上り回線の情報量を比較して、上り回線と下り回線に割り当てるタイムスロット数を決定する。このとき同期用制御チャネルを含む下り回線共通制御チャネル信号

の伝送に必要な個数のタイムスロット数は、優先的に下り回線に割り当て、それ以外のタイムスロットは、情報量を考慮して下り回線と上り回線に割り当てる。

【００８０】そして、同期用制御チャネルを含む下り回線共通制御チャネルを予め定められたタイムスロット間隔でフレーム内に配置し、そのタイムスロットを下り回線タイムスロットとする。

【００８１】更に、残る下り回線タイムスロットをフレーム内に配置していく。このとき、同期用制御チャネルを含む制御チャネル信号を伝送する下り回線タイムスロット直後のタイムスロット以外のタイムスロットを優先して下り回線タイムスロットを配置する。そして、その他のタイムスロットを上り回線タイムスロットとする。

【００８２】同期用制御チャネルを含む下り回線共通制御チャネルを配置する下り回線タイムスロットは、下り回線共通制御チャネルだけが配置されるのではなく、そのほかの下り回線チャネルも配置されることがあり、その場合は、配置された複数のチャネルの信号が多重されて伝送される。

【００８３】図２の(a)は、１６のタイムスロットの内、４個のタイムスロットを下り回線タイムスロット、１２個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、４、８、１２を下り回線タイムスロットとし、それ以外のタイムスロットを上り回線タイムスロットとしている。

【００８４】(b)は、８個のタイムスロットを下り回線タイムスロット、８個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、４、８、１２を同期用制御チャネルを含む下り回線共通制御チャネルを伝送する下り回線タイムスロットとし、更にタイムスロット２、６、１０、１４を下り回線タイムスロットとしており、それ以外のタイムスロット１、３、５、７、９、１１、１３、１５を上り回線タイムスロットとしている。

【００８５】(c)は、１２個のタイムスロットを下り回線タイムスロット、４個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、４、８、１２を同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送する下り回線タイムスロットとし、更にタイムスロット２、３、６、７、１０、１１、１４、１５を下り回線タイムスロットとしており、それ以外のタイムスロット１、５、９、１３を上り回線タイムスロットとしている。

【００８６】(d)は、１５個のタイムスロットを下り回線タイムスロット、１個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、４、８、１２を同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送する下り回線タイムスロットとし、更にタイムスロット２、３、５、６、７、９、１０、１１、１３、１４、１５を下り回線タイムスロットとしており、タイムスロット１を上り回線タイムスロットとしている。

【００８７】上記(c)、(d)では、上り回線タイムスロットは、同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送するタイムスロットの直後に位置している。

【００８８】タイムスロットの割り当ては、情報量の変化に応じて割り当てを手動で切り替えて変更してもよいし、新たな呼の接続や切断など情報量に変化があった場合や一定の時間間隔毎に自動的に割り当てし直したりしてもよい。

【００８９】ここで、移動局は、電源投入時に、まず、同期用制御チャネルに用いられている拡散符号で受信信号を逆拡散することにより同期用制御チャネル信号を検出し、基地局との同期を獲得する。

【００９０】このような条件下において、移動局は、電源投入時には、下り回線と上り回線のタイムスロットの割り当てを知らないが、予め同期用制御チャネルが３タイムスロット置きに配置されていることがわかっているので、相関値を４タイムスロット周期で積分していくことで、同期用制御チャネル信号のタイミングを検出することができる。

【００９１】この検出したタイミングで、同期用制御チャネルを含む共通制御チャネル信号の復号を行い、下り回線タイムスロットと上り回線タイムスロットの配置や各チャネル割り当てられたタイムスロットを識別する。

【００９２】その後、共通制御チャネルや個別制御チャネルを用いて接続処理を行い、ユーザー情報チャネルを確立する。移動局と基地局間のユーザー情報チャネルは、フレーム２０１内における下り回線と上り回線の配置が様々であることから、下り回線ユーザー情報チャネルの割り当てられたタイムスロットから上り回線ユーザー情報チャネルの割り当てられたタイムスロットまでに多数のタイムスロットがあり、時間間隔が大きい状態が生じる。

【００９３】上り回線の送信電力制御をオープンループ制御で行う場合、下り回線の伝搬路状態と上り回線の伝搬路状態の相関性を用いているため、時間間隔が大きいと相関性が低下して送信電力制御の精度の劣化を招く。

【００９４】しかし、下り回線共通制御チャネル信号が３タイムスロット置きに送信されているため、その下り回線共通制御チャネル信号を受信して受信品質を測定し、この受信品質に基づいて送信電力制御を行えば、受信品質を測定した下り回線のタイムスロットと送信電力制御をして送信する上り回線タイムスロットとの間の時間が、最大でも２タイムスロットとなり、効率的な送信電力制御が可能となる。

【００９５】なお、１フレームを構成するタイムスロットの個数は１６でなくともよい。また、共通制御チャネルを配置する下り回線の間隔は３タイムスロット置きで

なくてもよい。更に、共通制御チャネルを配置する下り回線タイムスロットは等間隔で配置しなくも、予め定められたパターンで周期性をもって配置すればよい。

【００９６】このように、実施の形態１によれば、基地局１００の制御手段１２５の制御によって、通信フレーム内のタイムスロットを予め定められた間隔置きに固定的な下り回線タイムスロットとして配置し、それ以外のタイムスロットについては、システム内の上り回線の総情報量と下り回線の総情報量との比に応じて、下り回線タイムスロットと上り回線タイムスロットとに分配し、同期用制御チャネルを含む制御チャネル信号は上記の固定的な下り回線タイムスロットにおいて伝送し、各通信チャネルの下り回線と上り回線は情報量に応じて必要な数量の上記下り回線タイムスロットと上り回線タイムスロットにそれぞれ割り当てて伝送することにより、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局における基地局との同期獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【００９７】（実施の形態２）図３は、本発明の実施の形態２に係る時分割複信ＣＤＭＡ移動体通信システムに適用される通信フレームのタイムスロットの割り当てを示すフレーム図を示す。

【００９８】但し、図３は、１フレーム３０１を１６個のタイムスロット０～１６に分割する例である。また、図３において、凡例で代表して示す枠３０２は、下り回線共通制御チャネルと下り回線ユーザ情報チャネルが配置されるタイムスロットを示し、枠３０３は、下り回線ユーザ情報チャネルだけが配置されるタイムスロット、枠３０４は、上り回線チャネルが配置されるタイムスロットを示す。

【００９９】図１に示した基地局１００の制御手段１２５は、まず、下り回線の情報量と上り回線の情報量を比較して、上り回線と下り回線に割り当てるタイムスロット数を決定する。

【０１００】このとき同期用制御チャネルを含む下り回線共通制御チャネル信号の伝送に必要な個数のタイムスロット数を、優先的に下り回線に割り当て、それ以外のタイムスロットを、情報量を考慮して下り回線と上り回線に割り当てる。

【０１０１】そして、同期用制御チャネルを含む下り回線共通制御チャネルをフレーム内に１タイムスロット置きに配置し、そのタイムスロットを下り回線タイムスロットとする。更に、その他の下り回線タイムスロットをフレーム内に配置し、残ったタイムスロットを上り回線タイムスロットとする。

【０１０２】同期用制御チャネルを含む下り回線共通制御チャネルを配置する下り回線タイムスロットは、下り回線共通制御チャネルだけが配置されるのではなく、そのほかの下り回線チャネルもは位置されることがあり、その場合は、配置された複数のチャネルの信号が多重されて伝送される。

【０１０３】図３の(ａ)は、８個のタイムスロットを下り回線タイムスロット、８個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、２、４、６、８、１０、１２、１４を、同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送する下り回線タイムスロットとしている。それ以外のタイムスロット１、３、５、７、９、１１、１３、１５を、上り回線タイムスロットとしている。

【０１０４】(ｂ)は、１２個のタイムスロットを下り回線タイムスロット、４個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、２、４、６、８、１０、１２、１４を、同期用制御チャネルを含む下り回線共通制御チャネルを伝送する下り回線タイムスロットとし、更にタイムスロット１、５、９、１３を、下り回線タイムスロットとしている。それ以外のタイムスロット３、７、１１、１５を、上り回線タイムスロットとしている。

【０１０５】(ｃ)は、１２個のタイムスロットを下り回線タイムスロット、４個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、２、４、６、８、１０、１２、１４を、同期用制御チャネルを含む下り回線共通制御チャネルを伝送する下り回線タイムスロットとし、更にタイムスロット１、３、５、９、１１、１３を、下り回線タイムスロットとしている。それ以外のタイムスロット７、１５を、上り回線タイムスロットとしている。

【０１０６】(ｄ)は、１５個のタイムスロットを下り回線タイムスロット、１個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、２、４、６、８、１０、１２、１４を、同期用制御チャネルを含む下り回線共通制御チャネルを伝送する下り回線タイムスロットとし、更にタイムスロット１、３、５、７、９、１１、１３を、下り回線タイムスロットとしている。そしてタイムスロット１５を、上り回線タイムスロットとしている。

【０１０７】このように図３では、上り回線タイムスロットを、必ず、同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送するタイムスロットの直後に配置している。

【０１０８】即ち、同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送するタイムスロットを１タイムスロット置きに配置することで、それ以外のどのタイムスロットに上り回線タイムスロットを配置しても、その上り回線タイムスロットの直前のタイムスロットは、必ず同期用制御チャネルを含む下り回線共通制御チャネルを伝送するタイムスロットとなる構成にすることができる。

【０１０９】タイムスロットの割り当ては、情報量の変化に応じて割り当てを手動で切り替えて変更してもよいし、新たな呼の接続や切断など情報量に変化があった場合や一定の時間間隔毎に自動的に割り当てし直したりしてもよい。

【０１１０】このような条件下において、図示せぬ移動局は、電源投入時に、まず、同期用制御チャネルに用いられている拡散符号で受信信号を逆拡散することにより同期用制御チャネルを検出して、基地局との同期を獲得する。

【０１１１】移動局は、電源投入時には、下り回線と上り回線のタイムスロットの割り当てを知らないが、相関値を２タイムスロット周期で積分していくことで、同期用制御チャネルのタイミングを検出することができる。

【０１１２】そして、検出したタイミングで同期用制御チャネルを含む共通制御チャネル信号の復号を行い、下り回線タイムスロットと上り回線タイムスロットの配置や各チャネル割り当てられたタイムスロットを識別し、共通制御チャネルや個別制御チャネルを用いて接続処理を行い、ユーザー情報チャネルを確立する。

【０１１３】移動局と基地局間のユーザー情報チャネルは、フレーム内における下り回線と上り回線の配置が様々であることから、下り回線ユーザー情報チャネルの割り当てられたタイムスロットから上り回線ユーザー情報チャネルの割り当てられたタイムスロットまでに多数のタイムスロットがあり、時間間隔が大きいような場合が生じる。

【０１１４】上り回線の送信電力制御をオープンループ制御で行う場合、下り回線の伝搬路状態と上り回線の伝搬路状態の相関性が低下して送信電力制御の精度の劣化を招いてしまう。しかし、共通制御チャネルが１タイムスロット置きに送信されているため、これを受信してこれの受信品質に基づいて送信電力制御を行えば、送信電力制御をして送信する上り回線タイムスロットの直前の下り回線タイムスロットの受信品質を用いることができるため、効果的な送信電力制御が可能となる。なお、１フレームを構成するタイムスロットの個数は１６でなくともよい。

【０１１５】このように、実施の形態２によれば、１タイムスロット置きのタイムスロットを固定的な下り回線タイムスロットとして、それ以外のタイムスロットについては、システム内の上り回線の総情報量と下り回線の総情報量の比に応じて、下り回線タイムスロット数と上り回線タイムスロットとに分配し、同期用制御チャネルを含む制御チャネル信号を、上記の固定的な下り回線タイムスロットにおいて伝送し、各通信チャネルの下り回線と上り回線は情報量に応じて必要な数量の上記下り回線タイムスロットと上り回線タイムスロットにそれぞれ割り当てて伝送することにより、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、移動局の基地局との同期の獲得時間が短く、また、オープンループ制御の送信電力制御が有効に機能させることができる。

【０１１６】（実施の形態３）図４は、本発明の実施の形態３に係る時分割複信ＣＤＭＡ移動体通信システムにおける移動局のブロック図を示す。

【０１１７】この図４に示す基地局４００は、符号化手段４０１と、拡散手段４０２と、増幅手段４０３と、Ｄ／Ａ変換手段４０４と、送信周波数変換手段４０５と、受信周波数変換手段４０６と、Ａ／Ｄ変換手段４０７と、分配手段４０８と、第１相関検出手段４０９及び第２相関検出手段４１０を有する相関検出部４１１と、第１復号手段４１２及び第２復号手段４１３を有する復号部４１４と、送受信アンテナ４１５と、送受信切り替え手段４１６と、制御手段４１７とを備えて構成されている。

【０１１８】符号化手段４０１は、上り回線チャネル信号４２１を符号化するものであり、拡散手段４０２は、その符号化信号４２２を拡散するものである。増幅手段４０３は、その拡散信号４２３を増幅するものである。

【０１１９】Ｄ／Ａ変換手段４０４は、そのディジタルの増幅信号４２４をアナログ信号４２５に変換するものであり、送信周波数変換手段４０５は、そのアナログ信号４２５を無線周波数の送信信号４２６に変換するものである。

【０１２０】送受信切り替え手段４１６は、送受信アンテナ４１５を送信側と受信側に切り替えて接続するものであり、上記送信信号４２６は送受信切り替え手段４１６を介して送受信アンテナ４１５から図１に示した基地局１００へ無線送信されるようになっている。

【０１２１】受信周波数変換手段４０６は、送受信アンテナ４１５で受信され、送受信切り替え手段４１６を介して送られてきた無線周波数の受信信号４２７をベースバンド周波数の信号４２８に変換するものである。

【０１２２】Ａ／Ｄ変換手段４０７は、そのベースバンド周波数の信号４２８をディジタル受信信号４２９に変換するものであり、分配手段４０８は、ディジタル信号に変換された受信信号４２９を各チャネル信号４３０，４３１に分配するものである。

【０１２３】各相関検出手段４０９，４１０は、下り回線共通個別チャネル信号４３０，４３１の相関検出を行うものであり、各復号手段４１２，４１３は、その各チャネルの相関検出信号４３２，４３３の復号を行い、これら各チャネルの復号信号４３４，４３５を出力するものである。また、制御手段４１７は、前記した各手段の制御を行うものである。

【０１２４】このような構成において、上り回線チャネル信号４２１が、符号化手段４０１で符号化され、フレーム組み立てされて、拡散手段４０２へ出力される。但し、その符号化は、誤り訂正符号化であってもよく、ま

た、その場合にはインターリーブ処理も施される。

【０１２５】拡散手段４０２においては、拡散符号が用いられて符号化信号４２２の周波数帯域が拡散され、この拡散信号４２３が増幅手段４０３へ出力される。但し、前記した拡散符号は、制御手段４１７から指示される構成であってもよい。

【０１２６】増幅手段４０３においては、拡散信号４２３が制御手段４１７の指示に応じて割り当てられたタイムスロットに配置され、更に、制御手段４１７の指示に応じて拡散信号４２３の振幅が増幅／低減される送信電力制御が行われ、Ｄ／Ａ変換手段へ出力される。

【０１２７】Ｄ／Ａ変換手段４０４においては、そのディジタルの増幅信号４２４がアナログ信号４２５に変換され、送信周波数変換手段４０５へ出力され、送信周波数変換手段４０５においては、アナログ信号４２５が無線周波数に変換され、この無線周波数の送信信号４２６が送受信切り替え手段４１６へ出力される。

【０１２８】送受信切り替え手段４１６においては、制御手段４１７の指示に応じて、送受信アンテナ４１５が、上り回線タイムスロットでは送信周波数変換手段４０５に、下り線タイムスロットでは受信周波数変換手段４０６に接続される。

【０１２９】即ち、上り回線タイムスロットでは、送信周波数変換手段４０５で無線周波数に変換された送信信号４２６が送受信アンテナ４１５から基地局１００に向けて送信される。

【０１３０】一方、下り回線タイムスロットでは、送受信アンテナ４１５で受信された基地局１００からの信号４２７が、受信周波数変換手段４０６へ出力される。

【０１３１】受信周波数変換手段４０６においては、受信信号４２７がベースバンド周波数に変換され、Ａ／Ｄ変換手段４０７へ出力される。Ｄ／Ａ変換手段４０７においては、その変換されたアナログ信号４２８がディジタル信号４２９に変換され、分配手段４０８へ出力される。

【０１３２】分配手段４０８においては、制御手段４１７の指示に応じて、ディジタル信号４２９が時間分離され、各相関検出手段４０９，４１０へ出力される。

【０１３３】各相関検出手段４０９，４１０においては、時間分離された信号４３０，４３１の逆拡散がそれぞれ行われ、これによって受信信号と拡散符号の相関値４３２，４３３が検出される。このとき、それぞれの拡散符号が、制御手段４１７から指示される構成であってもよい。検出された相関値４３２，４３３は、それぞれ各復号手段４１２，４１３へ出力されると共に、制御手段４１７へ出力される。

【０１３４】各復号手段４１２，４１３においては、相関値４３２，４３３に応じて下り回線共通制御チャネル信号４３４，４３５の復号が行われる。このとき、基地局１００で下り回線の誤り訂正符号化を行うのであれば、デインターリーブ処理を施して、誤り訂正復号する構成とする。また、相関検出手段４０９、復号手段４１２，４１４などは、各チャネル毎に設けなくても、時分割によって共通のものを使用してもよい。

【０１３５】ここで、移動局４００の電源投入時における基地局１００との同期の獲得について、図１に示したように３タイムスロット置きに同期用制御チャネルを含む下り回線共通制御チャネル信号を伝送するタイムスロットが配置されている場合を例に説明する。

【０１３６】移動局４００は、電源投入時には基地局１００との同期が確立されていないため、上り回線と下り回線のタイムスロットの割り当てやタイミングが把握できていない。

【０１３７】そこで、移動局４００は、図５に示すように、任意の時刻ｔ１を起点とする４タイムスロット長５０１の区間について、サンプリングタイミング毎に、受信信号と下り同期用制御チャネルの拡散符号との相関値を、４タイムスロット間隔で積分していく。

【０１３８】この積分回数を増やしていくと、雑音成分が低減されるため同期用制御チャネルのタイミングに一致する図５に示すサンプリングタイミング５０２における相関値の積分値が、他のサンプリングタイミングにおける相関値の積分値に比べて大きく検出される。

【０１３９】しかし、積分回数を増やしすぎると、移動局４００と基地局１００が同期していない分だけ、移動局４００のサンプリングタイミング自体がずれていくため同期用制御チャネルのタイミング５０２の検出が難しくなる。

【０１４０】同期用制御チャネルを含む共通制御チャネルが一定の間隔で配置されていないと、上記のような積分による雑音成分の除去が難しいため、同期用制御チャネルのタイミングを検出することが難しい。

【０１４１】しかし、上り回線と下り回線に割り当てるタイムスロット数が変化しても、同期用制御チャネルを含む共通制御チャネルが一定の間隔で配置されていれば、その周期で積分を行うことができるので同期用制御チャネルのタイミングの検出を容易にすることができる。

【０１４２】図４に示す移動局４００においては、そのような積分による同期の確率を制御手段４１７で行う構成で示してあるが、制御手段４１７とは別に図示せぬ同期手段を設けてもよい。

【０１４３】このように、実施の形態３によれば、受信信号の拡散符号との相関値を予め定められたタイムスロット間隔で積分して同期用制御チャネルを検出することにより、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局において基地局との同期を確立することができる。

【０１４４】（実施の形態４）図６は、本発明の実施の

形態４に係る時分割複信ＣＤＭＡ移動体通信システムに適用される通信フレームのタイムスロットの割り当てを示すフレーム図を示す。

【０１４５】但し、図６は、１フレーム６０１を１６個のタイムスロット０～１６に分割する例である。また、図６において、凡例で代表して示す枠６０２は、下り回線共通制御チャネルが配置されるタイムスロットを示し、枠６０３は、下り回線ユーザ情報チャネルが配置されるタイムスロット、枠６０４は、上り回線ユーザ情報チャネルが配置されるタイムスロットを示す。

【０１４６】即ち、１フレーム６０１を１６タイムスロットに分割して、タイムスロット０、２、４、６、８、１０、１２、１４の８個のタイムスロットに同期用制御チャネルを含む下り回線共通制御チャネルを配置し、タイムスロット１、５、９、１３に下り回線ユーザー情報チャネルを配置し、タイムスロット３、１１に上り回線ユーザー情報チャネルを配置している。

【０１４７】この図６を参照して、図４に示した移動局４００の制御手段４１７の送信電力制御動作について説明する。

【０１４８】下り回線ユーザー情報チャネルは、移動局４００との間の個別チャネルであるため、送信電力は移動局４００の受信品質が予め定められた基準を満たすように制御されている。

【０１４９】一方、下り回線共通制御チャネルは、共通チャネルであるため、移動局４００での受信品質を基準とした送信電力制御がなされているわけでなく、このため、フェージング変動によっては一時的に受信品質が劣化する。

【０１５０】しかし、上り回線の送信電力制御をオープンループ制御で行う場合は、上り回線と下り回線の伝搬路状態の同一性を利用して行うため、受信品質を測定する下り回線タイムスロットと送信する上り回線タイムスロットの間隔が大きいと、下り回線と上り回線の伝搬路状態の同一性は低下し、送信電力制御の精度が低下してしまう。

【０１５１】受信品質が高ければ伝搬路状態を推定する精度が高くなるが、送信までの間隔が大きくなると伝搬路状態が変化してしまう。

【０１５２】これらの点を考慮して、各タイムスロットでの受信品質に適切な重みをつけて合成して伝搬路状態を推定する。伝搬路状態の変動が速い場合には、送信するタイムスロット３の直前タイムスロット２の共通制御チャネルの重みを高め、他のタイムスロットの共通制御チャネルやユーザー情報チャネルの重みを低く設定する。但し、タイムスロット２の共通制御チャネルの重みの比率を１として、他のタイムスロットのチャネルの重みの比率を０としてもよい。

【０１５３】一方、伝搬路状態の変動が遅い場合には、伝送路状態を精度高く推定できるのでタイムスロット１のユーザー情報チャネルの重みを高くして、タイムスロット０とタイムスロット２の共通制御チャネルの重みを低く設定する。但し、タイムスロット１のユーザー情報チャネルの重みの比率を１として、他のタイムスロットの共通制御チャネルの重みの比率を０としてもよい。

【０１５４】なお、タイムスロット３の上り回線ユーザー情報チャネルの送信電力制御について記述したが、タイムスロット１１の上り回線ユーザー情報チャネルの送信電力制御についても同様である。

【０１５５】また、送信するタイムスロットの直前の３つのタイムスロットのチャネルに重みをつけて合成する例を示したが、当然ながらそれより前のタイムスロットの下り回線チャネルを利用してもよい。

【０１５６】この場合、上記の例は、送信するタイムスロットの４タイムスロット以上前のタイムスロットのチャネルの重みを０とした場合に相当する。また、上記の例では、共通制御チャネルを配置した下り回線タイムスロット以外の下り回線タイムスロットにユーザー情報チャネルが配置されているが、ユーザー情報チャネルが下り回線共通制御チャネルが配置されているタイムスロットと同じタイムスロットに配置されている場合でも同様である。

【０１５７】更に、ユーザー情報チャネルが上り回線だけに配置され、下り回線には配置されていない場合も考えられるが、これはユーザー情報チャネルの重みが比率を０としたものとして扱えばよい。

【０１５８】また、上記の例では、重みをつけて合成して伝送路状態を推定したものであるが、推定した伝搬路状態の時間的な変化量の推移から送信するタイムスロットでの伝搬路状態を予測して送信電力制御してもよい。

【０１５９】更に、上記ではオープンループ制御による送信電力制御のみを行う例であるが、下り回線を通して基地局から移動局に送信電力を指示するクローズドループ制御を併用するような送信電力制御であっても同様である。

【０１６０】このように、実施の形態４によれば、受信信号の拡散符号との相関値を予め定められたタイムスロット間隔で積分して同期用制御チャネルを検出することにより、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局において基地局との同期を確立することができる。

【０１６１】また、上り回線ユーザー情報チャネルがどの上り回線タイムスロットに配置されても、その直前のタイムスロットに配置されている下り回線共通制御チャネルの受信品質を測定することにより、伝搬路状態の変動が速い場合にも効果的なオープンループ制御の送信電力制御を行うことができる。

【０１６２】（実施の形態５）図７は、本発明の実施の形態７に係る時分割複信ＣＤＭＡ移動体通信システムに

適用される通信フレームのタイムスロットの割り当てを示すフレーム図を示す。

【０１６３】但し、図７は、１フレーム７０１を１６個のタイムスロット０～１６に分割する例である。また、図７において、凡例で代表して示す枠７０２は、下り回線共通制御チャネルが配置されるタイムスロットを示し、枠７０３は、下り回線ユーザ情報チャネルが配置されるタイムスロット、枠７０４は、上り回線ユーザ情報チャネルが配置されるタイムスロットを示す。

【０１６４】即ち、１フレーム７０１を１６タイムスロットに分割して、タイムスロット０、２、４、６、８、１０、１２、１４の８個のタイムスロットに同期用制御チャネルを含む下り回線共通制御チャネルを配置し、タイムスロット５、１０に下り回線ユーザー情報チャネルを配置し、タイムスロット３、１１に上り回線ユーザー情報チャネルを配置している。

【０１６５】この図７を参照して、図４に示した移動局４００の制御手段４１７の送信電力制御動作について説明する。但し、送信するタイムスロットの直前のタイムスロットに配置されている下り回線チャネルの重みの比率を１とし、その他の下り回線チャネルの重みの比率を０とした場合について説明する。

【０１６６】送信するタイムスロット３の直前のタイムスロット２には共通制御チャネルが配置されている。従って、タイムスロット３の送信電力制御は、タイムスロット２の下り回線共通制御チャネルの受信品質に基づいて行われる。

【０１６７】一方、送信するタイムスロット１１の直前のタイムスロット１０には共通制御チャネルとユーザー情報チャネルの両方が配置されている。従って、タイムスロット１１の送信電力制御は、タイムスロット１０の下り回線共通制御チャネルの受信品質とユーザー情報チャネルの受信品質の両方に基づいて行うことができる。

【０１６８】共通制御チャネルの受信品質とユーザー情報チャネルの受信品質の両方を測定するためには、２つの相関検出手段が必要である。どちらか一方に切り替えて受信品質の測定を測定できる構成とすることで、相関検出手段は１つで済む。

【０１６９】下り回線と上り回線のユーザー情報チャネルの配置がどのようなものであっても、下り回線共通制御チャネルの受信品質を測定する構成では、下り回線ユーザー情報チャネルが、上り回線ユーザー情報チャネルの配置されたタイムスロットの直前のタイムスロットに配置されている場合でも、精度の低い下り回線共通制御チャネルの受信品質に基づいて送信電力制御を行うことになる。

【０１７０】このため、送信電力制御の効果が劣化してしまうが、下り回線ユーザー情報チャネルが、上り回線ユーザー情報チャネルの配置されているタイムスロットの直前のタイムスロットに配置されている場合には、受信品質を測定するチャネルをユーザー情報チャネルに切り替える構成とすることで、精度高く測定可能なユーザー情報チャネルの受信品質を測定することができ、これによって上り回線ユーザー情報チャネルの送信電力制御を効果的に行うことができる。

【０１７１】このように、実施の形態５によれば、受信信号の拡散符号との相関値を予め定められたタイムスロット間隔で積分して同期用制御チャネルを検出することにより、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても、時間をかけることなく容易に移動局において基地局との同期を確立することができる。

【０１７２】また、上り回線ユーザー情報チャネルが、どの上り回線タイムスロットに配置されても、その直前のタイムスロットに配置されている下り回線共通制御チャネルの受信品質とユーザー情報チャネルの受信品質とを切り替えて測定することにより、伝搬路状態の変動が速い場合にも少ない個数の相関検出手段で効果的なオープンループ制御の送信電力制御を行うことができる。

【０１７３】

【発明の効果】以上の説明から明らかなように、本発明によれば、上下回線の情報量が非対称な場合に情報量に応じて上下回線のタイムスロットの割り当てを変化させても移動局における基地局との同期の獲得時間を短くすることができ、また、オープンループ制御の送信電力制御を有効に機能させることができる。

【図面の簡単な説明】

【図１】本発明の実施の形態１に係る時分割複信ＣＤＭＡ移動体通信システムにおける基地局のブロック図

【図２】実施の形態１の時分割複信ＣＤＭＡ移動体通信システムにおける通信フレームのタイムスロットの割り当てを示すフレーム図

【図３】本発明の実施の形態２に係る時分割複信ＣＤＭＡ移動体通信システムに適用される通信フレームのタイムスロットの割り当てを示すフレーム図

【図４】本発明の実施の形態３に係る時分割複信ＣＤＭＡ移動体通信システムにおける移動局のブロック図

【図５】実施の形態３の移動局が、任意の時刻を起点とする４タイムスロット長の区間についてサンプリングタイミング毎に受信信号と下り同期用制御チャネルの拡散符号との相関値を４タイムスロット間隔で積分した場合の積分結果図

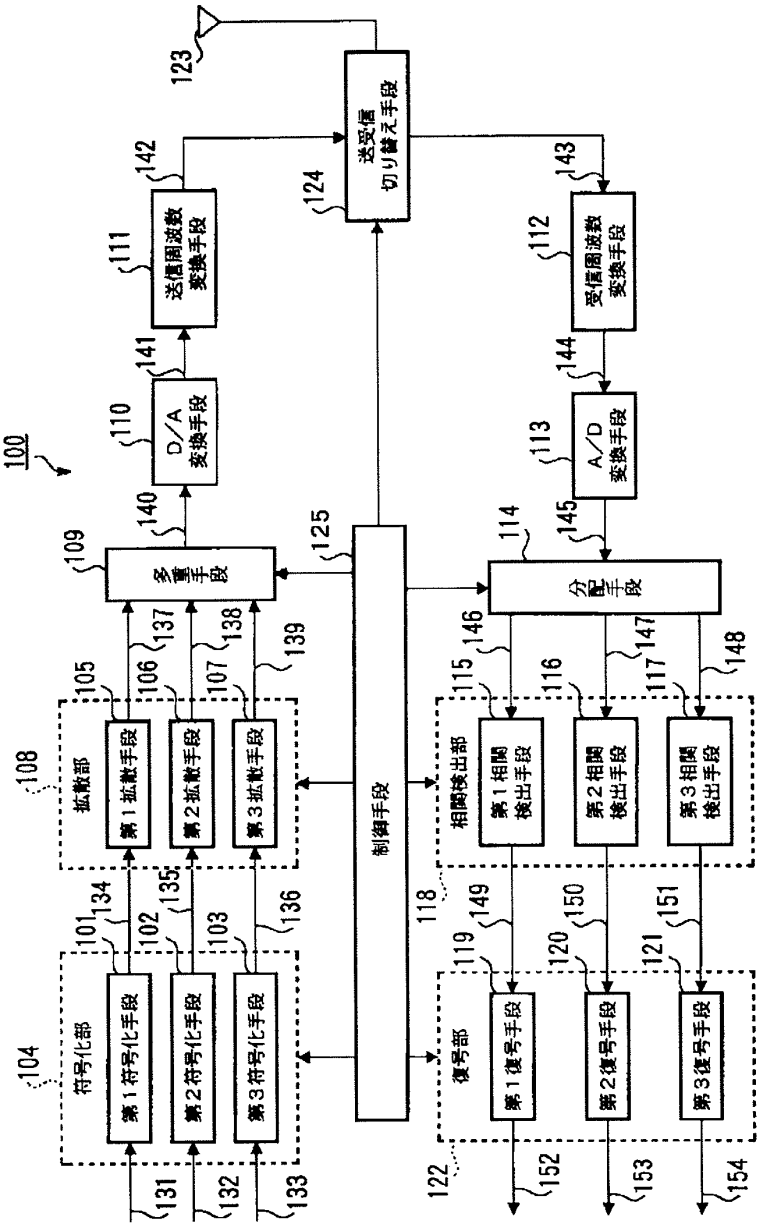
【図６】本発明の実施の形態４に係る時分割複信ＣＤＭＡ移動体通信システムに適用される通信フレームのタイムスロットの割り当てを示すフレーム図

【図７】本発明の実施の形態５に係る時分割複信ＣＤＭＡ移動体通信システムに適用される通信フレームのタイムスロットの割り当てを示すフレーム図

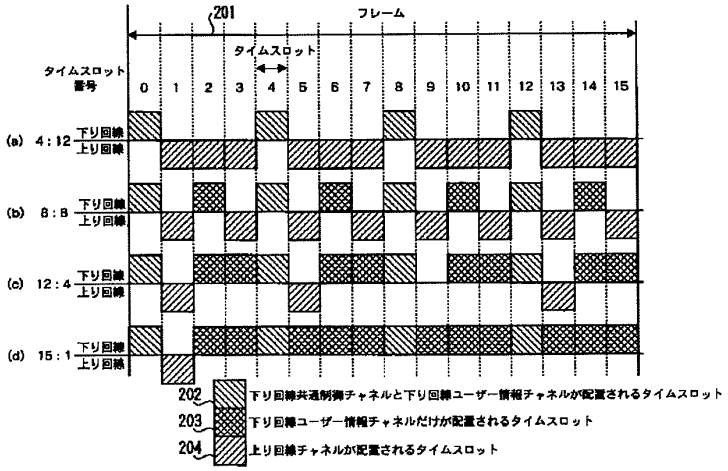
【図８】従来の時分割複信ＣＤＭＡ移動体通信システムにおけるフレーム図

【符号の説明】
１００　基地局
＊１２５，４１７　制御手段
＊　４００　移動局

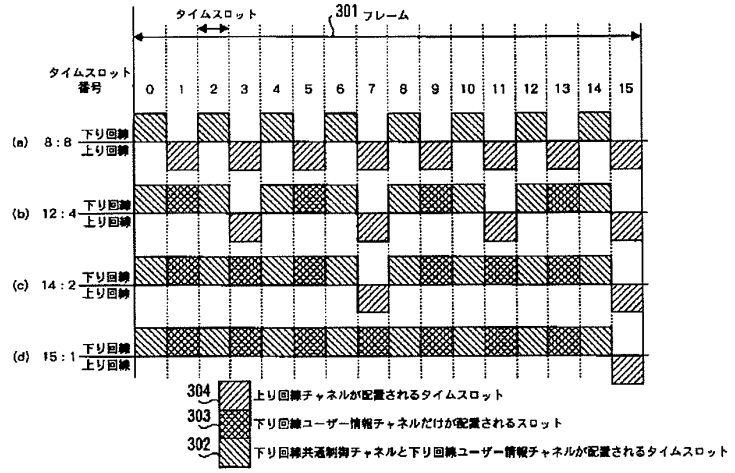
【図１】



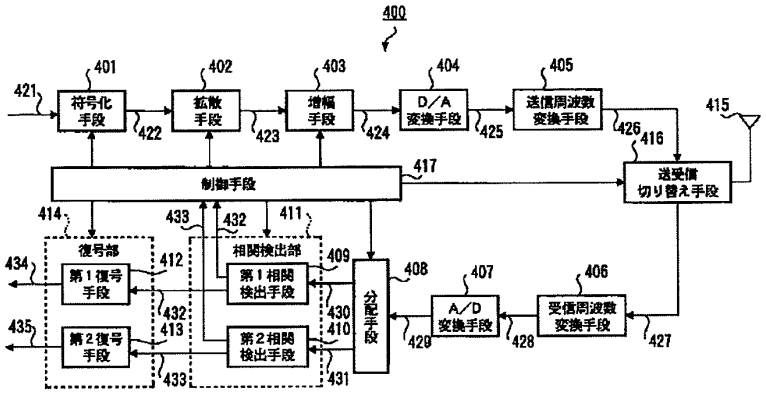
【図２】


201
フレーム
タイムスロット
タイムスロット番号
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
(a) 4:12 下り回線 上り回線
(b) 8:8 下り回線 上り回線
(c) 12:4 下り回線 上り回線
(d) 15:1 下り回線 上り回線
202 下り回線共通制御チャネルと下り回線ユーザー情報チャネルが配置されるタイムスロット
203 下り回線ユーザー情報チャネルだけが配置されるタイムスロット
204 上り回線チャネルが配置されるタイムスロット

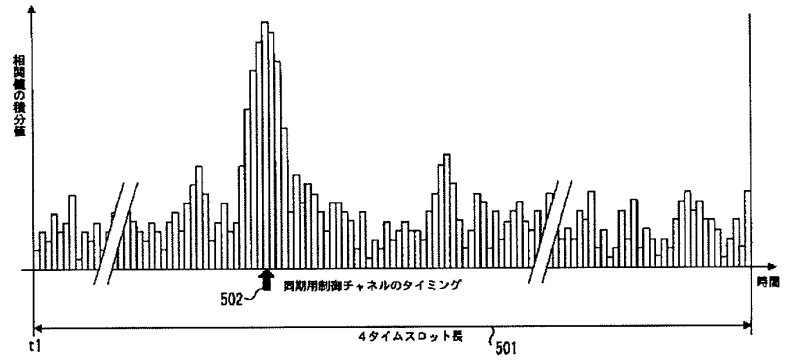
【図３】


タイムスロット
301 フレーム
タイムスロット番号
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
(a) 8:8 下り回線 上り回線
(b) 12:4 下り回線 上り回線
(c) 14:2 下り回線 上り回線
(d) 15:1 下り回線 上り回線
304 上り回線チャネルが配置されるタイムスロット
303 下り回線ユーザー情報チャネルだけが配置されるスロット
302 下り回線共通制御チャネルと下り回線ユーザー情報チャネルが配置されるタイムスロット

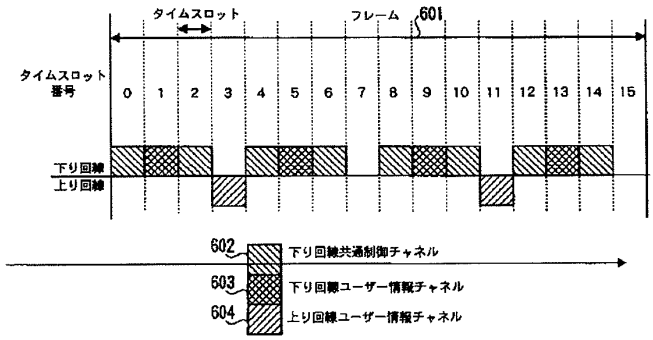
【図４】


400
401
402
403
404
405
421
符号化手段
422
拡散手段
423
増幅手段
424
D/A変換手段
425
送信周波数変換手段
426
415
416
制御手段
417
送受信切り替え手段
414
433
432
411
復号部
相関検出部
434
412
第１復号手段
第１相関検出手段
409
408
407
406
分配手段
A/D変換手段
受信周波数変換手段
435
432
413
第２復号手段
第２相関検出手段
430
410
429
428
427
433
431

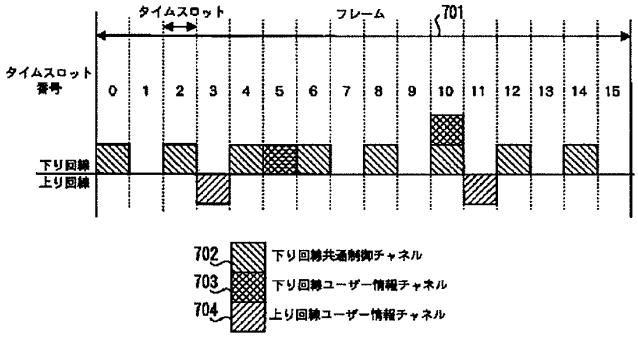
【図５】


相関値の積分値
502
同期用制御チャネルのタイミング
時間
t1
４タイムスロット長
501

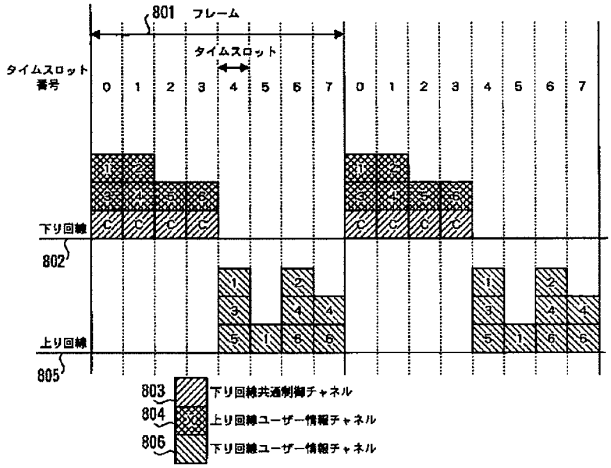
【図６】


タイムスロット
フレーム
601
タイムスロット番号
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
下り回線
上り回線
602
下り回線共通制御チャネル
603
下り回線ユーザー情報チャネル
604
上り回線ユーザー情報チャネル

【図７】



【図８】



フロントページの続き

(51)Int.Cl.[6]	識別記号	ＦＩ	
Ｈ０４Ｂ　1/707		Ｈ０４Ｊ　13/00	Ｄ
Ｈ０４Ｌ　12/28		Ｈ０４Ｌ　11/00	３１０Ｂ

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【公報種別】特許法第１７条の２の規定による補正の掲載
【部門区分】第７部門第３区分
【発行日】平成17年9月2日(2005.9.2)

【公開番号】特開平11-261544
【公開日】平成11年9月24日(1999.9.24)
【出願番号】特願平10-78317
【国際特許分類第７版】
　Ｈ０４Ｌ　5/16
　Ｈ０４Ｑ　7/36
　Ｈ０４Ｊ　3/00
　Ｈ０４Ｊ　3/06
　Ｈ０４Ｊ　3/22
　Ｈ０４Ｂ　1/707
　Ｈ０４Ｌ　12/28
【ＦＩ】
　Ｈ０４Ｌ　5/16
　Ｈ０４Ｊ　3/00　H
　Ｈ０４Ｊ　3/06　Z
　Ｈ０４Ｊ　3/22
　Ｈ０４Ｂ　7/26　１０５Ｄ
　Ｈ０４Ｊ　13/00　D
　Ｈ０４Ｌ　11/00　３１０Ｂ

【手続補正書】
【提出日】平成17年3月8日(2005.3.8)
【手続補正１】
【補正対象書類名】明細書
【補正対象項目名】発明の名称
【補正方法】変更
【補正の内容】
【発明の名称】基地局装置、移動局装置、および通信方法
【手続補正２】
【補正対象書類名】明細書
【補正対象項目名】特許請求の範囲
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項１】
　上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける基地局装置であって、
　前記複数のタイムスロットのうちあらかじめ定められたパターンで周期的に配置される固定位置のタイムスロットに、同期用制御チャネルを含む下り回線の共通制御チャネルを割り当てる割当手段と、
　前記固定位置のタイムスロット以外のタイムスロットに、上下回線の総情報量の比に応じて上り回線のユーザ情報チャネルおよび下り回線のユーザ情報チャネルを割り当てる制御手段と、
　を有することを特徴とする基地局装置。
【請求項２】
　前記割当手段は、

１タイムスロットおきに共通制御チャネルを割り当てることを特徴とする請求項１記載の基地局装置。
【請求項３】
上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける移動局装置であって、
あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信する受信手段と、
受信信号のサンプリングタイミングごとに前記同期用制御チャネル信号の相関検出を行う相関検出手段と、
前記固定下り回線タイムスロットが配置される間隔の時間長を積分周期として前記サンプリングタイミングごとの相関検出結果を積分する積分手段と、
前記積分周期において、前記相関検出結果の積分値が最も大きいサンプリングタイミングに前記同期用制御チャネル信号が含まれていると判定して同期を確立する同期手段と、
を有することを特徴とする移動局装置。
【請求項４】
上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける移動局装置であって、
あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信する受信手段と、
前記同期用制御チャネル信号を用いて受信品質を測定する測定手段と、
測定された受信品質に応じて上り回線スロットの送信電力制御を行う制御手段と、
を有することを特徴とする移動局装置。
【請求項５】
前記制御手段は、
前記固定下り回線タイムスロットと前記上り回線スロットとの間隔に応じて前記固定下り回線タイムスロットの同期用制御チャネル信号の受信品質に重み付けを行い、重み付け後の受信品質に応じて前記上り回線スロットの送信電力制御を行うことを特徴とする請求項４記載の移動局装置。
【請求項６】
前記測定手段は、
前記同期用制御チャネル信号と自装置に対して割り当てられた下り回線タイムスロットのユーザ情報チャネル信号とを用いて受信品質を測定することを特徴とする請求項４記載の移動局装置。
【請求項７】
前記測定手段は、
前記同期用制御チャネル信号と自装置に対して割り当てられた下り回線タイムスロットのユーザ情報チャネル信号とを切り替え、いずれか一方の信号を用いて受信品質を測定することする請求項４記載の移動局装置。
【請求項８】
基地局装置および移動局装置が上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムであって、
前記基地局装置は、
前記複数のタイムスロットのうちあらかじめ定められたパターンで周期的に配置される固定位置のタイムスロットに、同期用制御チャネルを含む下り回線の共通制御チャネルを割り当てる割当手段と、
前記固定位置のタイムスロット以外のタイムスロットに、上下回線の総情報量の比に応じて上り回線のユーザ情報チャネルおよび下り回線のユーザ情報チャネルを割り当てる制御手段と、を有し、
前記移動局装置は、

前記同期用制御チャネルの信号を含む信号を受信する受信手段と、
受信信号のサンプリングタイミングごとに前記同期用制御チャネルの信号の相関検出を行う相関検出手段と、
前記固定位置のタイムスロットが配置される間隔の時間長を積分周期として前記サンプリングタイミングごとの相関検出結果を積分する積分手段と、
前記積分周期において、前記相関検出結果の積分値が最も大きいサンプリングタイミングに前記同期用制御チャネルの信号が含まれていると判定して同期を確立する同期手段と、を有することを特徴とするＣＤＭＡ／ＴＤＤ移動体通信システム。
【請求項９】
上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、
前記複数のタイムスロットのうちあらかじめ定められたパターンで周期的に配置される固定位置のタイムスロットに、同期用制御チャネルを含む下り回線の共通制御チャネルを割り当てるステップと、
前記固定位置のタイムスロット以外のタイムスロットに、上下回線の総情報量の比に応じて上り回線のユーザ情報チャネルおよび下り回線のユーザ情報チャネルを割り当てるステップと、
を有することを特徴とする通信方法。
【請求項１０】
上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、
あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信するステップと、
受信信号のサンプリングタイミングごとに前記同期用制御チャネル信号の相関検出を行うステップと、
前記固定下り回線タイムスロットが配置される間隔の時間長を積分周期として前記サンプリングタイミングごとの相関検出結果を積分するステップと、
前記積分周期において、前記相関検出結果の積分値が最も大きいサンプリングタイミングに前記同期用制御チャネル信号が含まれていると判定して同期を確立するステップと、
を有することを特徴とする通信方法。
【請求項１１】
上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、
あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信するステップと、
前記同期用制御チャネル信号を用いて受信品質を測定するステップと、
測定された受信品質に応じて上り回線スロットの送信電力制御を行うステップと、
を有することを特徴とする通信方法。
【手続補正３】
【補正対象書類名】明細書
【補正対象項目名】００１６
【補正方法】削除
【補正の内容】

【手続補正４】
【補正対象書類名】明細書
【補正対象項目名】００１７
【補正方法】削除
【補正の内容】

【手続補正５】
【補正対象書類名】明細書
【補正対象項目名】００１８
【補正方法】削除
【補正の内容】

【手続補正６】
【補正対象書類名】明細書
【補正対象項目名】００１９
【補正方法】削除
【補正の内容】

【手続補正７】
【補正対象書類名】明細書
【補正対象項目名】００２０
【補正方法】削除
【補正の内容】

【手続補正８】
【補正対象書類名】明細書
【補正対象項目名】００２１
【補正方法】削除
【補正の内容】

【手続補正９】
【補正対象書類名】明細書
【補正対象項目名】００２２
【補正方法】削除
【補正の内容】

【手続補正１０】
【補正対象書類名】明細書
【補正対象項目名】００２３
【補正方法】削除
【補正の内容】

【手続補正１１】
【補正対象書類名】明細書
【補正対象項目名】００２４
【補正方法】削除
【補正の内容】

【手続補正１２】
【補正対象書類名】明細書
【補正対象項目名】００２５
【補正方法】削除
【補正の内容】

【手続補正１３】
【補正対象書類名】明細書

【補正対象項目名】００２６
【補正方法】削除
【補正の内容】

【手続補正１４】
【補正対象書類名】明細書
【補正対象項目名】００２７
【補正方法】削除
【補正の内容】

【手続補正１５】
【補正対象書類名】明細書
【補正対象項目名】００２８
【補正方法】削除
【補正の内容】

【手続補正１６】
【補正対象書類名】明細書
【補正対象項目名】００２９
【補正方法】削除
【補正の内容】

【手続補正１７】
【補正対象書類名】明細書
【補正対象項目名】００３０
【補正方法】変更
【補正の内容】
【００３０】
請求項1記載の基地局装置は、上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける基地局装置であって、前記複数のタイムスロットのうちあらかじめ定められたパターンで周期的に配置される固定位置のタイムスロットに、同期用制御チャネルを含む下り回線の共通制御チャネルを割り当てる割当手段と、前記固定位置のタイムスロット以外のタイムスロットに、上下回線の総情報量の比に応じて上り回線のユーザ情報チャネルおよび下り回線のユーザ情報チャネルを割り当てる制御手段と、を有する構成とした。
【手続補正１８】
【補正対象書類名】明細書
【補正対象項目名】００３２
【補正方法】変更
【補正の内容】
【００３２】
また、請求項2記載の基地局装置は、請求項1記載の基地局装置において、前記割当手段は、１タイムスロットおきに共通制御チャネルを割り当てる構成とした。
【手続補正１９】
【補正対象書類名】明細書
【補正対象項目名】００３４
【補正方法】変更
【補正の内容】
【００３４】
また、請求項3記載の移動局装置は、上り回線および下り回線がそれぞれ割り当てられ

た複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける移動局装置であって、あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信する受信手段と、受信信号のサンプリングタイミングごとに前記同期用制御チャネル信号の相関検出を行う相関検出手段と、前記固定下り回線タイムスロットが配置される間隔の時間長を積分周期として前記サンプリングタイミングごとの相関検出結果を積分する積分手段と、前記積分周期において、前記相関検出結果の積分値が最も大きいサンプリングタイミングに前記同期用制御チャネル信号が含まれていると判定して同期を確立する同期手段と、を有する構成とした。

【手続補正２０】
【補正対象書類名】明細書
【補正対象項目名】００３６
【補正方法】削除
【補正の内容】

【手続補正２１】
【補正対象書類名】明細書
【補正対象項目名】００３７
【補正方法】削除
【補正の内容】

【手続補正２２】
【補正対象書類名】明細書
【補正対象項目名】００３８
【補正方法】変更
【補正の内容】
【００３８】
また、請求項４記載の移動局装置は、上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける移動局装置であって、あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信する受信手段と、前記同期用制御チャネル信号を用いて受信品質を測定する測定手段と、測定された受信品質に応じて上り回線スロットの送信電力制御を行う制御手段と、を有する構成とした。
また、請求項５記載の移動局装置は、請求項４記載の移動局装置において、前記制御手段は、前記固定下り回線タイムスロットと前記上り回線スロットとの間隔に応じて前記固定下り回線タイムスロットの同期用制御チャネル信号の受信品質に重み付けを行い、重み付け後の受信品質に応じて前記上り回線スロットの送信電力制御を行う構成とした。

【手続補正２３】
【補正対象書類名】明細書
【補正対象項目名】００４０
【補正方法】変更
【補正の内容】
【００４０】
また、請求項６記載の移動局装置は、請求項４記載の移動局装置において、前記測定手段は、前記同期用制御チャネル信号と自装置に対して割り当てられた下り回線タイムスロットのユーザ情報チャネル信号とを用いて受信品質を測定する構成とした。

【手続補正２４】
【補正対象書類名】明細書
【補正対象項目名】００４２
【補正方法】変更

【補正の内容】
【００４２】
また、請求項７記載の移動局装置は、請求項４記載の移動局装置において、前記測定手段は、前記同期用制御チャネル信号と自装置に対して割り当てられた下り回線タイムスロットのユーザ情報チャネル信号とを切り替え、いずれか一方の信号を用いて受信品質を測定する構成とした。
【手続補正２５】
【補正対象書類名】明細書
【補正対象項目名】００４４
【補正方法】変更
【補正の内容】
【００４４】
また、請求項９記載の通信方法は、上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、前記複数のタイムスロットのうちあらかじめ定められたパターンで周期的に配置される固定位置のタイムスロットに、同期用制御チャネルを含む下り回線の共通制御チャネルを割り当てるステップと、前記固定位置のタイムスロット以外のタイムスロットに、上下回線の総情報量の比に応じて上り回線のユーザ情報チャネルおよび下り回線のユーザ情報チャネルを割り当てるステップと、を有するようにした。
【手続補正２６】
【補正対象書類名】明細書
【補正対象項目名】００４６
【補正方法】削除
【補正の内容】

【手続補正２７】
【補正対象書類名】明細書
【補正対象項目名】００４７
【補正方法】削除
【補正の内容】

【手続補正２８】
【補正対象書類名】明細書
【補正対象項目名】００４８
【補正方法】変更
【補正の内容】
【００４８】
また、請求項１０記載の通信方法は、上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信するステップと、受信信号のサンプリングタイミングごとに前記同期用制御チャネル信号の相関検出を行うステップと、前記固定下り回線タイムスロットが配置される間隔の時間長を積分周期として前記サンプリングタイミングごとの相関検出結果を積分するステップと、前記積分周期において、前記相関検出結果の積分値が最も大きいサンプリングタイミングに前記同期用制御チャネル信号が含まれていると判定して同期を確立するステップと、を有するようにした。
【手続補正２９】
【補正対象書類名】明細書
【補正対象項目名】００５０

【補正方法】削除
【補正の内容】

【手続補正３０】
【補正対象書類名】明細書
【補正対象項目名】００５１
【補正方法】削除
【補正の内容】

【手続補正３１】
【補正対象書類名】明細書
【補正対象項目名】００５２
【補正方法】変更
【補正の内容】
【００５２】
また、請求項１１記載の通信方法は、上り回線および下り回線がそれぞれ割り当てられた複数のタイムスロットからなる通信フレームを用いるＣＤＭＡ／ＴＤＤ移動体通信システムにおける通信方法であって、あらかじめ定められたパターンで周期的に配置される固定下り回線タイムスロットの同期用制御チャネル信号を含む信号を受信するステップと、前記同期用制御チャネル信号を用いて受信品質を測定するステップと、測定された受信品質に応じて上り回線スロットの送信電力制御を行うステップと、を有するようにした。
【手続補正３２】
【補正対象書類名】明細書
【補正対象項目名】００５３
【補正方法】削除
【補正の内容】

【手続補正３３】
【補正対象書類名】明細書
【補正対象項目名】００５４
【補正方法】削除
【補正の内容】

【手続補正３４】
【補正対象書類名】明細書
【補正対象項目名】００５５
【補正方法】削除
【補正の内容】

【手続補正３５】
【補正対象書類名】明細書
【補正対象項目名】００５６
【補正方法】削除
【補正の内容】

【手続補正３６】
【補正対象書類名】明細書
【補正対象項目名】００５７
【補正方法】削除
【補正の内容】

【手続補正３７】
【補正対象書類名】明細書
【補正対象項目名】００６２
【補正方法】変更
【補正の内容】
【００６２】
多重手段１０９は、その拡散によって得られる各チャネルの拡散信号１３７，１３８，１３９を多重するものであり、Ｄ／Ａ変換手段１１０は、その多重信号１４０をアナログ信号１４１に変換するものであり、送信周波数変換手段１１１は、アナログ信号１４１を無線周波数の送信信号１４２に変換するものである。
【手続補正３８】
【補正対象書類名】明細書
【補正対象項目名】００６４
【補正方法】変更
【補正の内容】
【００６４】
受信周波数変換手段１１２は、送受信アンテナ１２３で受信され、送受信切り替え手段１２４を介して送られてきた無線周波数の受信信号１４３をベースバンド周波数の信号１４４に変換するものである。
【手続補正３９】
【補正対象書類名】明細書
【補正対象項目名】００６９
【補正方法】変更
【補正の内容】
【００６９】
多重手段１０９においては、各拡散信号１３７～１３９が制御手段１２５の指示に応じてタイムスロットに配置されて時間多重される。この際、同一のタイムスロットに配置されたチャネルが加算多重される。但し、加算多重処理が行われる場合、それぞれのチャネルの拡散信号１３７～１３９毎に振幅を制御する送信電力制御がなされるようにしてもよい。
【手続補正４０】
【補正対象書類名】明細書
【補正対象項目名】０１０５
【補正方法】変更
【補正の内容】
【０１０５】
（ｃ）は、１４個のタイムスロットを下り回線タイムスロット、２個のタイムスロットを上り回線タイムスロットとした場合の例であり、タイムスロット０、２、４、６、８、１０、１２、１４を、同期用制御チャネルを含む下り回線共通制御チャネルを伝送する下り回線タイムスロットとし、更にタイムスロット１、３、５、９、１１、１３を、下り回線タイムスロットとしている。それ以外のタイムスロット７、１５を、上り回線タイムスロットとしている。
【手続補正４１】
【補正対象書類名】明細書
【補正対象項目名】０１３１
【補正方法】変更
【補正の内容】
【０１３１】
受信周波数変換手段４０６においては、受信信号４２７がベースバンド周波数に変換さ

れ、Ａ／Ｄ変換手段４０７へ出力される。Ａ／Ｄ変換手段４０７においては、その変換されたアナログ信号４２８がディジタル信号４２９に変換され、分配手段４０８へ出力される。

【手続補正４２】
【補正対象書類名】明細書
【補正対象項目名】０１３４
【補正方法】変更
【補正の内容】
【０１３４】
各復号手段４１２，４１３においては、相関値４３２，４３３に応じて下り回線共通制御チャネル信号４３４，４３５の復号が行われる。このとき、基地局１００で下り回線の誤り訂正符号化を行うのであれば、デインターリーブ処理を施して、誤り訂正復号する構成とする。また、相関検出手段４０９、４１０、復号手段４１２、４１３などは、各チャネル毎に設けなくても、時分割によって共通のものを使用してもよい。

PATENT ABSTRACTS OF JAPAN

(11)Publication number : **2006-197318**
(43)Date of publication of application : **27.07.2006**

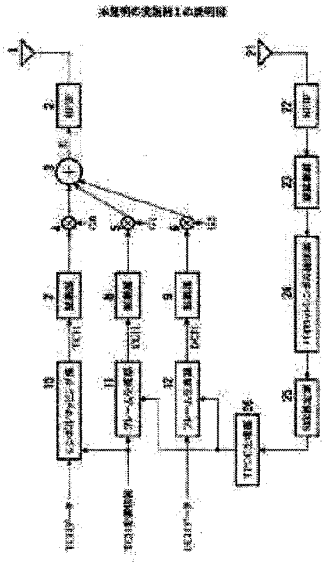
(51)Int.Cl. *H04B 7/26 (2006.01)*
H04B 1/69 (2006.01)

(21)Application number : **2005-007508**
(22)Date of filing : **14.01.2005**

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(54) MOBILE RADIO COMMUNICATION SYSTEM AND RADIO COMMUNICATION APPARATUS

(57)Abstract:
PROBLEM TO BE SOLVED: To reduce power consumption in a mobile radio communication system comprising base stations and a mobile station, and radio communication apparatuses constituting the base stations and the mobile station.
SOLUTION: The mobile radio communication system and radio communication apparatuses comprise at least a movable radio communication apparatus among a plurality of radio communication apparatuses; multiplex channels comprising at least a traffic channel for transmitting packets, a control channel for transmitting control information for packet receiving, and a channel for transmitting information comprising transmission power control information; and perform radio communication between one radio communication apparatus such as a base station and the other radio communication apparatus such as a mobile station. The system and the apparatuses include a means which transmits the transmission power control information by the channel for transmitting the information comprising the transmission power control information in a constant period longer than the length of a packet from the one radio communication apparatus to the other radio communication apparatus, and transmits the transmission power control information by the control channel when the packet is transmitted by the traffic channel.



(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2006-197318
(P2006-197318A)
(43)公開日　平成18年7月27日(2006.7.27)

(51)Int.Cl.			F I			テーマコード（参考）
H04B	***7/26***	***(2006.01)***	H04B	7/26	102	5K022
H04B	***1/69***	***(2006.01)***	H04B	7/26	X	5K067
			H04J	13/00	C	

審査請求 未請求　請求項の数 8　OL　（全 16 頁）

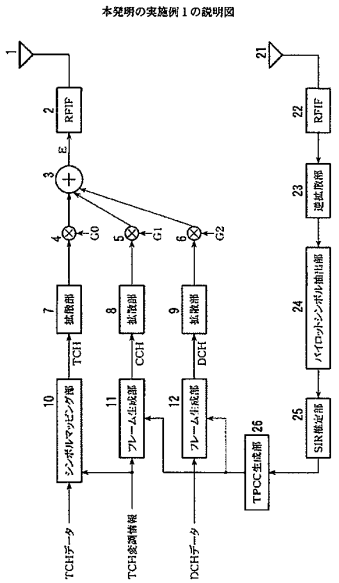
(21)出願番号　特願2005-7508 (P2005-7508)
(22)出願日　平成17年1月14日 (2005.1.14)

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最終頁に続く

(54)【発明の名称】移動無線通信システム及び無線通信装置

(57)【要約】
【課題】　基地局や移動局を含む移動無線通信システム及び基地局や移動局を構成する無線通信装置に関し、消費電力の低減を図る。
【解決手段】　複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、パケットの受信用の制御情報を伝送する制御チャネルと、送信電力制御情報を含む情報を伝送するチャネルとを少なくとも含むチャネルを多重化して、基地局等の一方の無線通信装置と移動局等の他方の無線通信装置との間で無線通信する移動無線通信システム及び無線通信装置であって、一方の無線通信装置から他方の無線通信装置に対して、送信電力制御情報を含む情報を伝送するチャネルによる前記送信電力制御情報を、パケットの長さに比較して長い一定の周期で送信し、トラフィックチャネルによるパケットの送信時に、制御チャネルにより送信電力制御情報を送信する手段を備えている。
【選択図】　図1



【特許請求の範囲】
【請求項１】
複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、前記パケットの受信用の制御情報を伝送する制御チャネルと、前記送信電力制御情報を含む情報を伝送するチャネルとを少なくとも含むチャネルを多重化して、一方の無線通信装置と他方の無線通信装置との間で無線通信する移動無線通信システムに於いて、
一方の無線通信装置から他方の無線通信装置に対して前記個別チャネルによる前記送信電力制御情報を前記パケットの長さに比較して長い一定の周期で送信し、前記トラフィックチャネルによるパケットの送信時に、前記制御チャネルにより前記送信電力制御情報を送信する手段を前記一方の無線通信装置に設けた
ことを特徴とする移動無線通信システム。
【請求項２】
複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、前記パケットの受信用の制御情報を伝送する制御チャネルと、送信電力制御情報を含む情報を伝送する個別チャネルとを少なくとも含むチャネルを多重化して、一方の無線通信装置と他方の無線通信装置との間で無線通信する移動無線通信システムに於いて、
前記一方の無線通信装置から前記他方の無線通信装置に対して前記一定の周期で前記送信電力制御情報を含む情報を伝送するチャネルにより送信する前記送信電力制御情報の受信直前と、前記制御チャネルにより送信した前記送信電力制御情報の受信直後とに、パイロット信号を送信する手段を前記他方の無線通信装置に設けた
ことを特徴とする移動無線通信システム。
【請求項３】
前記一方の無線通信装置から前記他方の無線通信装置に送信する前記送信電力制御情報を、前記送信電力制御情報を含む情報を伝送するチャネルにより送信する第１の送信電力制御情報と、前記制御チャネルにより送信する第２の送信電力制御情報とし、前記パイロット信号を、前記第１の送信電力制御情報の送信周期より短い周期で送信する手段を前記他方の無線通信装置に設けたことを特徴とする前記請求項２記載の移動無線通信システム。
【請求項４】
前記一方の無線通信装置から前記他方の無線通信装置に送信する前記送信電力制御情報を、前記送信電力制御情報を含む情報を伝送するチャネルにより送信する第１の送信電力制御情報と、前記制御チャネルにより送信する第２の送信電力制御情報として、前記第１の送信電力制御情報による送信電力制御量に対して、前記第２の送信電力制御情報による送信電力制御量を同一又は大きくしたことを特徴とする請求項１乃至３項の何れか１項記載の移動無線通信システム。
【請求項５】
共有チャネルを介してデータを送信する移動無線通信システムに於ける該データを送信する無線通信装置に於いて、
ある移動局に対する送信電力制御情報を、所定の周期で送信するとともに、該ある移動局に対して前記データを送信する場合に、その受信に必要となる制御情報に送信電力制御情報を含めて送信する送信部を備えた
ことを特徴とする無線通信装置。
【請求項６】
前記所定の周期で送信する送信電力制御情報による送信電力制御量に対して、前記制御情報に含まれる送信電力制御情報による送信電力制御量を同一又は大きくしたことを特徴とする請求項５記載の無線通信装置。
【請求項７】
共有チャネルを介してデータを送信する移動無線通信システムに於ける該データを受信

する無線通信装置に於いて、
パイロット信号を前記データの受信に必要な制御情報の受信に連動させて送信する送信部を備えた
ことを特徴とする無線通信装置。
【請求項８】
前記送信部は、更に所定の周期でパイロット信号を送信するとともに、該周期に対して前記連動して送信するパイロット信号の送信周期を短くしたことを特徴とする請求項７記載の無線通信装置。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、送信電力制御情報に従って送信電力を制御して無線通信を行う移動無線通信システム及び無線通信装置に関する。
【背景技術】
【０００２】
移動局や基地局等の無線通信装置間で無線通信を行う移動無線通信システムは、例えば、図５に示すように、複数の分散配置された無線通信装置としての基地局５０ａ，５０ｂと、基地局のサービスエリア内で移動しながら無線通信を行う移動局５０ｃとを含むものであり、５１ａ，５１ｂ，５１ｃはアンテナ、５２ａ，５２ｂはネットワーク（図示を省略）に対するインタフェース部、５３ａ，５３ｂ，５３ｃは増幅器や変復調部等を含む送受信部、５４ａ，５４ｂ、５４ｃは信号処理部を示す。
【０００３】
移動局５０ｃと基地局５０ａ，５０ｂとの間の無線通信方式は、Ｗ－ＣＤＭＡ（Ｗｉｄｅ－Ｃｏｄｅ Ｄｉｖｉｓｉｏｎ Ｍｕｌｔｉｐｌｅ Ａｃｃｅｓｓ）方式や、ＯＦＤＭ（Ｏｒｔｈｏｇｏｎａｌ Ｆｒｅｑｕｅｎｃｙ Ｄｉｖｉｓｉｏｎ Ｍｕｌｔｉｐｌｅｘｉｎｇ）方式等の各種の方式が適用されている。又移動局５０ｃから基地局５０ａ，５０ｂに送信する信号が、基地局に於いて充分な電力で受信され、且つ大き過ぎる電力で送信することによる他のチャネルへの干渉を最小とする為に、基地局からの下りリンク（個別チャネル）により、一定間隔で送信電力制御情報（ＴＰＣ；Ｔｒａｎｓｍｉｔ Ｐｏｗｅｒ Ｃｏｎｔｒｏｌ）を送信し、移動局５０ｃは、この送信電力制御情報に従って送受信部５３ｃの送信電力を増減する送信電力制御が行われる。尚、この送信電力情報は、移動局から送信されるパイロット信号等の受信レベル（品質）に応じて生成しており、受信レベル（品質）が高い場合は、送信電力を下げる指示、受信レベル（品質）が低い場合は、送信電力を上げる指示を行うものである。
【０００４】
又パケット通信を行う移動無線通信システムに於いては、パケットの正常受信時にＡＣＫ信号、異常受信時にＮＡＣＫ信号を個別チャネル等を介して送信するが、パケット送信頻度が低く、ＡＣＫ信号又はＮＡＣＫ信号等の受信応答信号の送信が必要でない期間であっても、このＡＣＫ信号等を送信する際のこの個別チャネルの電力が適当となるように、別個の個別チャネルを介してパイロット信号等を継続して送信するものである。従って、このような信号を送信する為に、移動局は電力を消費している。
【０００５】
又Ｗ－ＣＤＭＡ方式に於いて、下りリンクで最大１４Ｍｂｐｓの伝送速度を実現する為のＨＳＤＰＡ（Ｈｉｇｈ Ｓｐｅｅｄ Ｄｏｗｎｌｉｎｋ Ｐａｃｋｅｔ Ａｃｃｅｓｓ）が規定されている。この方式は、パケット伝送について、適応符号化変調方式を採用するもので、例えば、ＱＰＳＫ（Ｑｕａｄｒａｔｕｒｅ Ｐｈａｓｅ Ｓｈｉｆｔ Ｋｅｙｉｎｇ）変調方式と、１６値ＱＡＭ（Ｑｕａｄｒａｔｕｒｅ Ａｍｐｌｉｔｕｄｅ Ｍｏｄｕｌａｔｉｏｎ）方式とを、無線伝搬路の状態に対応した伝送レートとなるように、適応的に切替えるものである。
【０００６】

このＨＳＤＰＡ方式は、Ｈ－ＡＲＱ（Ｈｙｂｒｉｄ Ａｕｔｏｍａｔｉｃ Ｒｅｐｅａｔ Ｒｅｑｕｅｓｔ）方式を採用しており、例えば、図５に示す移動無線通信システムに於ける移動局５０ｃは、基地局５０ａからのパケットデータを受信して、誤りを検出すると、基地局５０ａへ再送信の要求を行うことにより、その基地局５０ａからはパケットデータの再送信が行われ、移動局５０ｃは、受信済みのデータと、再送信されたデータとの双方を用いて誤り訂正復号化処理を行う手段が適用される。

【０００７】

又ＨＳＤＰＡ方式に於ける主な無線チャネルは、ＨＳ－ＳＣＣＨ（Ｈｉｇｈ Ｓｐｅｅｄ－Ｓｈａｒｅｄ Ｃｏｎｔｒｏｌ Ｃｈａｎｎｅｌ）、ＨＳ－ＰＤＳＣＨ（Ｈｉｇｈ Ｓｐｅｅｄ－Ｐｈｙｓｉｃａｌ Ｄｏｗｎｌｉｎｋ Ｓｈａｒｅｄ Ｃｈａｎｎｅｌ）、ＨＳ－ＤＰＣＣＨ（Ｈｉｇｈ Ｓｐｅｅｄ－Ｄｅｄｉｃａｔｅｄ Ｐｈｙｓｉｃａｌ Ｃｏｎｔｒｏｌ Ｃｈａｎｎｅｌ）等がある。

【０００８】

前述の無線チャネルのＨＳ－ＳＣＣＨとＨＳ－ＰＤＳＣＨとは、移動無線通信システムの場合の基地局から移動局への下り方向（Ｄｏｗｎｌｉｎｋ）の共有チャネルであり、又ＨＳ－ＳＣＣＨは、ＨＳ－ＰＤＳＣＨにより送信するデータに関する各種パラメータを送信する制御チャネルである。この各種パラメータとしては、例えば、ＨＳ－ＰＤＳＣＨによりデータを送信する変調方式を示す変調タイプ情報や、拡散符号のコード数、送信データに対して施したレートマッチング処理のパターン情報等が含まれる。

【０００９】

又ＨＳ－ＤＰＣＣＨは、移動無線通信システムの場合の移動局から基地局への上り方向（Ｕｐｌｉｎｋ）の個別制御チャネルであり、ＨＳ－ＰＤＳＣＨにより受信したデータの正常受信の可否に対応したＡＣＫ信号、ＮＡＣＫ信号を移動局から基地局へ送信する場合に使用するものである。例えば、受信データのＣＲＣエラー検出の場合等に於いては、ＮＡＣＫ信号を基地局へ送信し、それを基に基地局は再送処理を行うことになる。又ＨＳ－ＤＰＣＣＨは、基地局からの受信信号の受信品質（例えば、ＳＩＲ（Ｓｉｇｎａｌ ｔｏ Ｉｎｔｅｒｆｅｒｅｎｃｅ Ｒａｔｉｏ））を測定し、その結果を、ＣＱＩ（Ｃｈａｎｎｅｌ Ｑｕａｌｉｔｙ Ｉｎｄｉｃａｔｏｒ）として基地局へ定期的に送信する為に使用するものである。基地局は、このＣＱＩに基づいて、下り方向の無線環境の良否を判定し、良好の場合は、より高速でデータを送信可能とする変調方式に切替え、反対に不良の場合は、より低速でデータを送信する変調方式等に切替えるものである。

【００１０】

図６は、前述のＨＳＤＰＡに於けるチャネル構成説明図であり、前述のＣＰＩＣＨ，Ｐ－ＣＣＰＣＨ，ＨＳ－ＳＣＣＨ，ＨＳ－ＰＤＳＣＨ，ＨＳ－ＤＰＣＣＨの概要を示すもので、ＣＰＩＣＨ（Ｃｏｍｍｏｎ Ｐｉｌｏｔ Ｃｈａｎｎｅｌ）と、Ｐ－ＣＣＰＣＨ（Ｐｒｉｍａｒｙ Ｃｏｍｍｏｎ Ｃｏｎｔｒｏｌ Ｐｈｙｓｉｃａｌ Ｃｈａｎｎｅｌ）とは、それぞれ下り方向の共通チャネルである。又ＣＰＩＣＨは、移動局に於いてチャネル推定、セルサーチ、同一セル内に於ける他の下り物理チャネルのタイミング基準として利用するチャネルであり、所謂パイロット信号を送信する為のチャネルである。又Ｐ－ＣＣＰＣＨは、報知情報を送信する為のチャネルである。又ＨＳ－ＳＣＣＨ，ＨＳ－ＰＤＳＣＨ，ＨＳ－ＤＰＣＣＨは、前述の制御チャネルを示し、ＨＳ－ＤＰＣＣＨにより前述のＣＱＩ及びＡＣＫ／ＮＡＣＫを送信する。

【００１１】

又１５スロットにより１フレーム（１０ｍｓ）を構成し、ＣＰＩＣＨは、タイミング基準として用いる為に、Ｐ－ＣＣＰＣＨ，ＨＳ－ＳＣＣＨのフレーム先頭は、ＣＰＩＣＨのフレーム先頭と一致しているが、ＨＳ－ＰＤＳＣＨのフレーム先頭は、２スロット分遅延している。これは、移動局がＨＳ－ＰＤＳＣＨの復調を行う為に必要な情報を先に受信識別する為である。即ち、変調方式や拡散コード等の情報を予めＨＳ－ＳＣＣＨにより予告通知することにより、ＨＳ－ＰＤＳＣＨの復調、復号を行う為である。又ＨＳ－ＳＣＣＨ，ＨＳ－ＰＤＳＣＨは、３スロットで１サブフレームを構成している。

【００１２】
又ＨＳ－ＳＣＣＨによる情報は、３ＧＰＰ　ＴＳ２５．２１２ｖ．５．７．０を参照すると、次の（ａ）～（ｇ）に示すものである。
（ａ）Ｘｃｃｓ（Ｃｈａｎｎｅｌｉｚａｔｉｏｎ　Ｃｏｄｅ　Ｓｅｔ　Ｉｎｆｏｒｍａｔｉｏｎ）；７ビット；ＨＳ－ＤＳＣＨに使用されている拡散コードの情報。
（ｂ）Ｘｍｓ（Ｍｏｄｕｌａｔｉｏｎ　Ｓｃｈｅｍｅ　Ｉｎｆｏｒｍａｔｉｏｎ）；１ビット；ＨＳ－ＤＳＣＨに使用されている変調方式。
（ｃ）Ｘｔｂｓ（Ｔｒａｎｓｐｏｒｔ－Ｂｌｏｃｋ　Ｓｉｚｅ　Ｉｎｆｏｒｍａｔｉｏｎ）；６ビット；誤り訂正符号化される送信データブロックサイズ。
（ｄ）Ｘｈａｐ（Ｈｙｂｒｉｄ－ＡＲＱ　Ｐｒｏｃｅｓｓ　Ｉｎｆｏｒｍａｔｉｏｎ）；３ビット；再送制御を行うプロセス番号。
（ｅ）Ｘｒｖ；（Ｒｅｄｕｎｄａｎｃｙ　ａｎｄ　Ｃｏｎｓｔｅｌｌａｔｉｏｎ　Ｖｅｒｓｉｏｎ）；３ビット；レートマッチングのパラメータ。
（ｆ）Ｘｎｄ；Ｎｅｗ　Ｄａｔａ　Ｉｎｄｉｃａｔｏｒ；１ビット；新規データかどうかの情報。
（ｇ）Ｘｕｅ；ＵＥ　Ｉｄｅｎｔｉｔｙ；１６ビット；ユーザ識別情報。
以上のように、合計３７ビットの構成であり、このＨＳ－ＳＣＣＨを受信することにより、ＨＳ－ＤＳＣＨで用いられている変調方式、拡散コード、誤り訂正のパラメータ等を知ることができる。従って、それらのパラメータに従ってＨＳ－ＤＳＣＨを復調，復号することができる。

【００１３】
前記（ａ）Ｘｃｃｓは、ＨＳ－ＰＤＳＣＨによりデータを送信する時の拡散コードを示すもので、例えば、マルチコード数とコードオフセットとの組み合わせを示すことができる。又（ｂ）Ｘｍｓは、変調方式が例えばＱＰＳＫか１６値ＱＡＭかを“１”、“０”により示すものである。又（ｃ）Ｘｔｂｓは、ＨＳ－ＰＤＳＣＨの１サブフレームで送信するデータサイズを算出する為のデータであり、（ｄ）Ｘｈａｐは、Ｈ－ＡＲＱのプロセス番号を示すもので、送信したデータのブロックに対して連続した番号とし、再送時には、前回の送信データのプロセス番号と同一の番号を用いる。

【００１４】
又（ｅ）Ｘｒｖは、ＨＳ－ＰＤＳＣＨの再送信時に於ける冗長バージョンパラメータ、コンスタレーションパラメータを示すもので、新規送信や再送信に於いてパラメータを更新する場合と、変更しない場合とがある。又（ｆ）Ｘｎｄは、ＨＳ－ＰＤＳＣＨの送信ブロックが新規ブロックか再送ブロックかを示すデータであって、新規ブロックは、“１”、“０”を交互に変化させ、再送ブロックは、前と同一として変化させないことにより、区別するものである。又（ｇ）Ｘｕｅは、移動局（ユーザ）の識別情報である。

【００１５】
前述のＨＳ－ＳＣＣＨを受信することにより、ＨＳ－ＰＤＳＣＨで適用されている変調方式、拡散コード、誤り訂正のパラメータ等を認識して、ＨＳ－ＰＤＳＣＨの復調、復号を行うことができる（例えば、非特許文献１、非特許文献２、非特許文献３及び非特許文献４参照）。

【００１６】
又Ｗ－ＣＤＭＡシステムのエンハンスとして、Ｆ－ＤＰＣＨ（Ｆｒａｃｔｉｏｎａｌ　Ｄｅｄｉｃａｔｅｄ　Ｐｈｙｓｉｃａｌ　Ｃｈａｎｎｅｌ）が提案されている（例えば、非特許文献５参照）。これは、複数のユーザの個別チャネルのパイロット信号と送信電力制御情報（ＴＰＣ）のみに、同じ拡散コードを割り当て、複数ユーザを同じスロット内に時分割多重化して送信するものである。

【００１７】
ＨＳ－ＰＤＳＣＨ等の共有チャネル（トラフィックチャネル）でデータ受信を行うユーザは、トラフィックデータをＨＳ－ＰＤＳＣＨで伝送している為に、個別チャネル（例えば、ＨＳチャネルとは異なるＤＰＣＨ）で伝送すべきデータが殆ど無い場合が多い。しか

し、送信電力制御の為にＴＰＣビットやパイロット信号を伝送する必要があるから、個別チャネル（ＤＰＣＨ）をＨＳ－ＰＤＳＣＨと同時に接続している必要があり、データ伝送の必要が無いにも拘わらず１コードを占有し、結果的には同様なユーザが複数存在することでリソース不足を招く問題が起きていた。又Ｆ－ＤＰＣＨは、この問題を解決すべく、個別チャネルで伝送するデータの無い複数のユーザのＴＰＣビットとパイロット信号とを、同じコードで拡散処理し、時分割多重を行うことにより、リソース不足を解消しようとするものである。

【００１８】

又Ｆ－ＤＰＣＨと類似の構成として、電力制御チャネルを専用に用意し、その中に複数のユーザのＴＰＣビットを時間多重で埋め込み、又パケット伝送を行うトラフィックチャネルにも同様のＴＰＣビットを埋め込み、伝送するパケットが発生している場合には、電力制御チャネルによるＴＰＣビットを無効情報に変更することにより、トラフィックチャネルによるＴＰＣビットを優先させて、送信電力制御を行う無線通信装置が提案されている（例えば、特許文献１参照）。

【特許文献１】特開平１１－１４５９０１号公報

【非特許文献１】Ａｒｉ Ｈｏｔｔｉｎｅｎ，Ｏｌａｖ Ｔｉｒｋｋｏｎｅｎ，Ｒｉｓｔｏ Ｗｉｃｈｍａｎ著“Ｍｕｌｔｉ－ａｎｔｅｎｎａ Ｔｒａｎｓｃｅｉｖｅｒ Ｔｅｃｈｎｉｑｕｅｓ ｆｏｒ ３Ｇ ａｎｄ Ｂｅｙｏｎｄ”

【非特許文献２】３ＧＰＰ ＴＳ ２５．２１１ ｖ５．５．０（３ｒｄ Ｇｅｎｅｒａｔｉｏｎ Ｐａｒｔｎｅｒｓｈｉｐ Ｐｒｏｊｉｃｔ；Ｔｅｃｈｎｉｃａｌ Ｓｐｅｃｉｆｉｃａｔｉｏｎ Ｇｒｏｕｐ Ｒａｄｉｏ Ａｃｃｅｓｓ Ｎｅｔｗｏｒｋ；Ｐｈｙｓｉｃａｌ ｃｈａｎｎｅｌｓ ａｎｄ ｍａｐｐｉｎｇ ｏｆ ｔｒａｎｓｐｏｒｔ ｃｈａｎｎｅｌｓ ｏｎｔｏ ｐｈｙｓｉｃａｌ ｃｈａｎｎｅｌｓ（ＦＤＤ）

【非特許文献３】３ＧＰＰ ＴＳ ２５．２１３ ｖ５．５．０（３ｒｄ Ｇｅｎｅｒａｔｉｏｎ Ｐａｒｔｎｅｒｓｈｉｐ Ｐｒｏｊｉｃｔ；Ｔｅｃｈｎｉｃａｌ Ｓｐｅｃｉｆｉｃａｔｉｏｎ Ｇｒｏｕｐ Ｒａｄｉｏ Ａｃｃｅｓｓ Ｎｅｔｗｏｒｋ；Ｓｐｒｅａｄｉｎｇ ａｎｄ ｍｏｄｕｌａｔｉｏｎ（ＦＤＤ）

【非特許文献４】３ＧＰＰ ＴＳ ２５．２１４ ｖ５．７．０（３ｒｄ Ｇｅｎｅｒａｔｉｏｎ Ｐａｒｔｎｅｒｓｈｉｐ Ｐｒｏｊｉｃｔ；Ｔｅｃｈｎｉｃａｌ Ｓｐｅｃｉｆｉｃａｔｉｏｎ Ｇｒｏｕｐ Ｒａｄｉｏ Ａｃｃｅｓｓ Ｎｅｔｗｏｒｋ；Ｐｈｙｓｉｃａｌ ｌａｙｅｒ ｐｒｏｃｅｄｕｒｅｓ（ＦＤＤ）

【非特許文献５】３ＧＰＰ Ｒ１－０３１０７３

【発明の開示】

【発明が解決しようとする課題】

【００１９】

前述のＷ－ＣＤＭＡ方式に於ける上りリンクでは、個別チャネル（ＤＰＣＨ）の送信電力制御（ＴＰＣ）が行われている。この送信電力制御（ＴＰＣ）は、ＴＰＣビットと呼ばれる送信電力制御情報をスロット単位で、基地局から移動局にフィードバックすることによって、移動局の送信電力制御が行われるものである。一方、ＨＳ－ＰＤＳＣＨ等の共有チャネルを用いたパケット通信方式を適用した場合、自局宛てのデータがないにもかかわらず、受信応答信号を送信する際の送信電力が適当に維持されるように、上り、下りのＤＰＣＨを介してパイロット信号、ＴＰＣビット等を常時定期的に送信する為、コードリソースを占有することになるから、コードリソースの不足が生じる問題があり、又移動局は、常時パイロット信号を送信する必要があるから、消費電力が大きくなる問題があった。

【００２０】

又Ｗ－ＣＤＭＡ方式に、前述のＦ－ＤＰＣＨを適用して、複数のＡ－ＤＰＣＨを時分割多重によってまとめることにより、コードリソースの有効利用を図る手段が提案されているが、送信電力制御（ＴＰＣ）ビットは、スロット単位で送信されるものであるから、多数のユーザに対して総て多重化することができない問題がある。即ち、同一のエリア内でパケット伝送を行う移動局の収容可能数を多くできない問題がある。又上りリンクについ

ては、常時送信するものと仮定されているから、移動局は、パケット伝送の有無に拘わらず、送信電力制御の為のパイロット信号等の送信を行うことになる。従って、消費電力を抑制することが困難であった。即ち、移動局は、比較的小型の電池を電源として送受信処理するものであるから、消費電力を低減しないと、長時間のパケット伝送を継続することができなくなる。

【００２１】

又前述の電力制御チャネルとトラフィックチャネルとによりＴＰＣビットを伝送する従来の構成に於いては、トラフィックチャネルによりＴＰＣビットを伝送する場合は、電力制御チャネルによるＴＰＣビットとの矛盾が生じないように、電力制御チャネル側のＴＰＣビットを無効化する処理が必要である。従って、処理が複雑化する問題と共に低消費電力化を行うことは困難である問題がある。また、電力制御チャネルは、送信しようとする制御パケットがない場合に送信されるものであり、周期的に送信されるものでなく、電力制御が安定化しない。

【００２２】

本発明は、前述の従来の問題点を解決するものであり、送信電力制御を、低消費電力且つ所望の精度で実行可能とすることを目的とする。

【課題を解決するための手段】

【００２３】

本発明の移動無線通信システムは、複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、パケットの受信用の制御情報を伝送する制御チャネルと、送信電力制御情報を含む情報を伝送するチャネルとを少なくとも含むチャネルを多重化して、一方の無線通信装置と他方の無線通信装置との間で無線通信する移動無線通信システムに於いて、一方の無線通信装置から他方の無線通信装置に対して、送信電力制御情報を含む情報を伝送するチャネルによる送信電力制御情報を、パケットの長さに比較して長い一定の周期で送信し、トラフィックチャネルによるパケットの送信時に、制御チャネルにより、送信電力制御情報を送信する手段を前記一方の無線通信装置に設けている。

【００２４】

又複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、パケットの受信用の制御情報を伝送する制御チャネルと、送信電力制御情報を含む情報を伝送するチャネルとを少なくとも含むチャネルを多重化して、一方の無線通信装置と他方の無線通信装置との間で無線通信する移動無線通信システムに於いて、一方の無線通信装置から他方の無線通信装置に対して、一定の周期で送信電力制御情報を含む情報を伝送するチャネルにより送信する送信電力制御情報の受信直前と、制御チャネルにより送信した送信電力制御情報の受信直後とに於いて、パイロット信号を送信する手段を前記他方の無線通信装置に設けている。

【００２５】

又一方の無線通信装置から他方の無線通信装置に送信する送信電力制御情報を、送信電力制御情報を含む情報を伝送するチャネルにより送信する第１の送信電力制御情報と、制御チャネルにより送信する第２の送信電力制御情報とし、パイロット信号を、第１の送信電力制御情報の送信周期より短い周期で送信する手段を前記他方の無線通信装置に設けている。

【００２６】

又一方の無線通信装置から他方の無線通信装置に送信する送信電力制御情報を、送信電力制御情報を含む情報を伝送するチャネルにより送信する第１の送信電力制御情報と、制御チャネルにより送信する第２の送信電力制御情報として、第１の送信電力制御情報による送信電力制御量に対して、第２の送信電力制御情報による送信電力制御量を同一又は大きくする。

【００２７】

又共有チャネルを介してデータを送信する移動無線通信システムに於ける該データを送

信する無線通信装置に於いて、ある移動局に対する送信電力制御情報を、所定の周期で送信するとともに、該ある移動局に対して前記データを送信する場合に、その受信に必要となる制御情報に送信電力制御情報を含めて送信する送信部を備えている。

又前記前記所定の周期で送信する送信電力制御情報による送信電力制御量に対して、前記制御情報に含まれる送信電力制御情報による送信電力制御量を同一又は大きくした。

又共有チャネルを介してデータを送信する移動無線通信システムに於ける該データを受信する無線通信装置に於いて、パイロット信号を前記データの受信に必要な制御情報の受信に連動させて送信する送信部を備えている。

又前記送信部は、更に所定の周期でパイロット信号を送信するとともに、該周期に対して前記連動して送信するパイロット信号の送信周期を短くした。

【発明の効果】

【００２８】

本発明に於いては、送信電力制御情報を含む情報を伝送するチャネルによる送信電力制御情報を一定の周期で送信すると共に、パケット送信時に、制御チャネルにより送信電力制御情報を送信するもので、パケット送信を行わない期間では、送信電力制御情報を含む情報を伝送するチャネルによる送信電力制御情報を比較的長い一定の周期で送信することにより、送信電力制御は、その比較的長い一定の周期毎に行うことになるから、消費電力の低減を図ることができる。又パイロット信号を、連続的ではなく、所定の周期で送信すると共に、パケット送信有りを示す場合にも送信する構成とすることにより、連続的にパイロット信号を送信する場合に比較して、消費電力を一層低減することができる。又送信電力制御情報を、送信電力制御情報を含む情報を伝送するチャネルによる第１の送信電力制御情報と、制御チャネルによる第２の送信電力制御情報として、第２の送信電力制御情報による電力制御量を大きくすることにより、送信電力制御の応答性を向上することができる。

又送信電力制御情報を所定の周期で送信することで、送信電力制御の安定性を保ちつつ、データの受信のための制御情報にも送信電力制御情報を追加して、送信電力制御情報の送信の粗密をデータ送信に合わせて制御できる。

又パイロット信号の送信を省略する部分も形成できるため、無線送信に要する電力の削減を図ることができる。

【発明を実施するための最良の形態】

【００２９】

本発明の移動無線通信システムは、複数の無線通信装置の中の少なくとも移動する無線通信装置を含み、パケットを伝送するトラフィックチャネルと、パケットの受信用の制御情報を伝送する制御チャネルと、送信電力制御情報を含む情報を伝送する送信電力制御情報を含む情報を伝送するチャネルとを少なくとも含むチャネルを多重化して、一方の無線通信装置と他方の無線通信装置との間で無線通信する移動無線通信システムに於いて、一方の無線通信装置、例えば、基地局から他方の無線通信装置、例えば、移動局に対して、個別チャネルによる送信電力制御情報を、パケットの長さに比較して長い一定の周期で送信し、トラフィックチャネルによるパケットの送信時に、制御チャネルにより、送信電力制御情報を送信する手段を、前記基地局としての一方の無線通信装置に設ける。

【００３０】

又本発明の無線通信装置は、移動無線通信システムに於ける無線通信装置、例えば、基地局に於いて、送信電力制御情報を含む情報を伝送するチャネルによる送信電力制御情報を、トラフィックチャネルによるパケットの長さに比較して長い一定の周期で、例えば、移動局に送信し、且つトラフィックチャネルによるパケットの送信時に、制御チャネルにより送信電力制御情報を送信する送信手段を備えている。

尚、送信電力制御情報は、基本的に全て有効なもの（受信側において、送信電力制御に用いるもの）とする。

【実施例１】

【００３１】

図１は、本発明の実施例１の無線通信装置の説明図であり、一方と他方との無線通信装置を含み、ＣＤＭＡ方式を適用した移動無線通信システムに於ける一方の無線通信装置、例えば、基地局に相当する無線通信装置の要部を示すものである。同図に於いて、１，２１はアンテナ、２は高周波処理部（ＲＦＩＦ）、３は多重化部、４，５，６は乗算部、７，８，９は拡散部、１０はシンボルマッピング部、１１，１２はフレーム生成部、２２は高周波処理部（ＲＦＩＦ）、２３は逆拡散部、２４はパイロットシンボル抽出部、２５はＳＩＲ（Ｓｉｇｎａｌ ｔｏ Ｉｎｔｅｒｆｅｒｅｎｃｅ Ｒａｔｉｏ）推定部、２６はＴＰＣＣ（送信電力制御情報）生成部を示す。なお、ＴＣＨデータと、ＴＣＨ変調情報と、ＤＣＨデータとの生成処理部及び基地局とした場合のネットワークとのインタフェース部分については、既に知られている各種の構成を適用できるものであり、それらの構成は、図示を省略している。

【００３２】

アンテナ１に接続された高周波処理部２は、符号化、変調等を行う手段と、送信電力増幅部とを含む構成を有し、又アンテナ２１に接続された高周波処理部２２は、低雑音増幅部と、復調、復号等を行う手段とを含む構成を有する。又ＴＣＨ（トラフィックチャネル、例えば、ＨＳ－ＰＤＳＣＨ）データを、シンボルマッピング部１０に入力し、又ＴＣＨ変調情報（例えば、ＨＳ－ＳＣＣＨで送信する情報）を、シンボルマッピング部１０とフレーム生成部１１とに入力し、又ＤＣＨ（個別チャネル（ＤＰＣＨ））データを、フレーム生成部１２に入力する。シンボルマッピング部１０に於いては、ＴＣＨデータを、ＴＣＨ変調情報に従ってマッピングし、トラフィックチャネルＴＣＨとして拡散部７に入力して、割り当てられた拡散コードにより拡散処理し、乗算部４に入力する。

【００３３】

又フレーム生成部１１は、ＴＣＨ変調情報と、ＴＰＣＣ生成部２６からの送信電力制御情報とを含むフレームを生成して、制御チャネルＣＣＨとして拡散部８に入力し、割り当てられた拡散コードにより拡散処理し、乗算部５に入力する。又フレーム生成部１２は、ＤＣＨデータと、ＴＰＣＣ生成部２６からの送信電力制御情報とを含むフレームを生成して、個別チャネルＤＣＨとして拡散部９に入力し、割り当てられた拡散コードにより拡散処理し、乗算部６に入力する。即ち、ＴＣＨデータと、ＴＣＨ変調情報と、ＤＣＨデータとは、それぞれ異なる拡散コードにより拡散処理される。又乗算部４，５，６は、チャネル毎の送信電力比を設定するゲインＧ０，Ｇ１，Ｇ２を乗算し、多重化部３に於いてチップ毎の加算処理により多重化し、高周波処理部２に入力して、変調及び増幅処理し、アンテナ１から送信する。この場合の拡散部７，８，９に於ける拡散コードはそれぞれ相違させるものである。

【００３４】

又アンテナ２１により受信した信号を高周波処理部２２に於いて増幅、復調、復号等の処理を行って、逆拡散部２３により逆拡散処理し、パイロットシンボル抽出部２４によりパイロットシンボルを抽出（例えば、上りのＤＰＣＨの受信により抽出）する。このパイロットシンボルの複数のシンボルから、ＳＩＲ推定部２５に於いて、ＳＩＲ（Ｓｉｇｎａｌ ｔｏ Ｉｎｔｅｒｆｅｒｅｎｃｅ Ｒａｔｉｏ）を推定し、この推定によるＳＩＲ値をＴＰＣＣ生成部２６に入力する。このＴＰＣＣ生成部２６は、ＳＩＲ値を閾値と比較して、例えば、大きい場合には、ＴＰＣＣ＝－１、小さい場合には、ＴＰＣＣ＝＋１とした送信電力制御情報ＴＰＣＣをフレーム生成部１１，１２に入力する。なお、後述のように、１段階毎の送信電力制御のみでなく、複数段階による送信電力制御を可能とするＴＰＣＣ構成とすることも可能である。

【００３５】

従って、ＴＣＨ変調情報と送信電力制御情報ＴＰＣＣとは、フレーム生成部１１により制御チャネルＣＣＨ（例えば、ＨＳ－ＳＣＣＨ）により送信することになり、又ＤＣＨデータと送信電力制御情報ＴＰＣＣとは、個別チャネルＤＣＨ（ＤＰＣＨ）により送信される。即ち、送信電力制御情報は、制御チャネルＣＣＨと個別チャネルＤＣＨとの両方により送信するものである。その場合、個別チャネルＤＣＨにより、比較的長い周期で、送信

電力制御情報ＴＰＣＣを送信し、制御チャネルＣＣＨによりパケットの有無を通知してパケット伝送を行う場合に、そのパケット対応のタイミングにより、送信電力制御情報ＴＰＣＣを送信する。このような送信電力制御情報の送信については、図示を省略した制御部からの制御により行うことができる。従って、パケット対応のタイミングに従った送信電力制御情報ＴＰＣＣは、個別チャネルにより送信する送信電力制御情報ＴＰＣＣより短い周期となるから、送信電力制御の追従性を向上することができる。又個別チャネルにより送信する送信電力制御情報による電力制御量に比較して、制御チャネルにより送信する送信電力制御制御情報による電力制御量を大きくすることも可能である。

【００３６】

図２は、本発明の実施例１の無線通信装置の要部の説明図であり、ＣＤＭＡ方式を適用した一方と他方との無線通信装置を含む移動無線通信システムに於ける他方の無線通信装置、例えば、移動局に相当する無線通信装置の要部を示すものであり、３１，４１はアンテナ、３２は高周波処理部（ＲＦＩＦ）、３３はＣＣＨ逆拡散部、３４はＴＣＨ逆拡散部，３５はＤＣＨ逆拡散部，３６はビット判定部、３７はＴＰＣＣ抽出部、３８は送信電力制御部、４２は高周波処理部（ＲＦＩＦ）、４３は乗算部、４４は多重化部、４５，４６，４７は拡散部を示す。なお、下りリンクトラフィックデータの処理部や、上りリンクトラフィックデータの処理部等は、既に知られている各種の構成を適用することができるもので、図示を省略している。

【００３７】

アンテナ３１は、例えば、図１に示すアンテナ１から送信した送信信号を受信し、この受信信号を、高周波処理部３２に入力する。この高周波処理部３２は、低雑音増幅部と、復調、復号等を行う手段を含む構成を有する。又アンテナ４１は、例えば、図１に示すアンテナ２１に対して、高周波処理部４２からの信号を送信する為のものであり、高周波処理部４２は、符号化、変調等を行う手段と、送信電力増幅部とを含む構成を有するものである。又高周波処理部３２により復調、復号化して、ＣＣＨ逆拡散部３３と、ＴＣＨ逆拡散部３４と、ＤＣＨ逆拡散部３５とに入力し、送信側に於いて拡散処理した拡散コードにより、それぞれ逆拡散処理する。

【００３８】

ＴＣＨ逆拡散部３４により、送信側からのＴＣＨ変調情報を逆拡散処理してビット判定部３６に入力し、且つＴＣＨ逆拡散部３４により、送信側からのＴＣＨ変調情報を逆拡散処理してビット判定部３６に入力し、ビット判定により、下りリンクトラフィックデータを出力する。又ＴＣＨ逆拡散部３４とＤＣＨ逆拡散部３５とによりそれぞれ逆拡散して、送信電力制御情報を含む逆拡散出力をＴＰＣＣ抽出部３７に入力し、送信電力制御情報を抽出して、送信電力制御部３８に入力する。

【００３９】

又上りリンクトラフィックデータと、パイロットシンボルと、下りリンクトラフィックデータ出力を処理する受信処理結果に基づいたＡｃｋ，Ｎａｃｋとをそれぞれの拡散部４５，４６，４７に入力して、それぞれ異なる拡散コードにより拡散処理し、多重化部４４により多重化し、送信電力制御部３８から乗算部４３に入力する制御値により、送信電力を制御して、高周波処理部４２により符号化、変調等の処理を行い、且つ増幅してアンテナ４１から送信する。その場合の送信電力制御部３８は、ＴＰＣＣ抽出部３７により抽出した送信電力制御情報ＴＰＣＣ＞０の場合は、送信電力Ｐｔｘを前回の値に対して＋１ｄＢとし、反対に送信電力制御情報ＴＰＣＣ＜０の場合は、送信電力Ｐｔｘを前回の値に対して－１ｄＢするもので、更新された送信電力Ｐｔｘに対応した値を乗算部４３に入力することになる。なお、前述のように、送信電力制御情報ＴＰＣＣの構成として、複数ビットを用いることにより、送信電力制御のステップを複数段階で上昇又は下降するように制御することも可能である。

【００４０】

図３は、本発明の実施例１の送信電力制御の説明図であり、個別チャネルＤＣＨ（Ｄｅｄｉｃａｔｅｄ　Ｃｈａｎｎｅｌ）と、制御チャネルＣＣＨ（Ｃｏｎｔｒｏｌ　Ｃｈａｎ

ｎｅｌ）と、トラフィックチャネルＴＣＨ（Ｔｒａｆｆｉｃ　Ｃｈａｎｎｅｌ）と、上りＡｃｋ，Ｎａｃｋ送信と、上りｐｉｌｏｔ（パイロット信号）送信とについて示すものであり、この上りＡｃｋ，Ｎａｃｋ送信に関係なく、上りパイロット信号は、連続的に送信する場合を示し、その場合の送信電力の大きさを、それぞれの高さで例示している。又個別チャネルＤＣＨによる送信電力制御情報ＴＰＣＣを、第１の送信電力制御情報、制御チャネルＣＣＨによる送信電力制御情報ＴＰＣＣを、第２の送信電力制御情報とすると、第１の送信電力制御情報は、スロット内の斜線を施した自局宛ＴＰＣＣとして示すように、同一スロット内に、他局宛ＴＰＣＣと共に自局宛ＴＰＣＣが伝送される場合と、自局宛ＴＰＣＣを含まないスロットとを有するものである。即ち、自局宛ＴＰＣＣの第１の送信電力制御情報は、所定の比較的長い一定の周期で送信するものである。この周期は、予め、送受信側で設定することができる。又制御チャネルＣＣＨによる自局宛ＴＰＣＣ、即ち、第２の送信電力制御情報は、パケットの送信に対応したものとする。従って、第２の送信電力制御情報は、第１の送信電力制御情報の送信周期より短いパケットの送信周期に従った周期で、送信電力制御情報ＴＰＣＣが伝送される。

【００４１】

このように、送信電力制御情報ＴＰＣＣは、パケット伝送を行わない期間では、第１の送信電力制御情報の比較的長い周期で送信することになり、それに対応して、比較的長い周期に於いて送信電力制御を行うことになる。又パケット伝送を行う期間では、パケットの伝送周期に従って第２の送信電力制御情報を送信することになるから、迅速な送信電力制御が可能となる。又パケット伝送を行わない期間では、余分な送信電力制御を省略することになるから、消費電力の低減を図ることができる。又パケット伝送を行う期間では、第１及び第２の送信電力制御情報を送信することにより、無線伝播路に於けるフェージング等の状態変化に対しても、迅速に送信電力の制御が可能となる。

【実施例２】

【００４２】

図４は、本発明の実施例２の送信電力制御の説明図であり、Ｆ－ＤＰＣＨ（Ｆｒａｃｔｉｏｎａｌ　Ｄｅｄｉｃａｔｅｄ　Ｐｈｙｓｉｃａｌ　Ｃｈａｎｎｅｌ）を適用した場合を示す。このチャネルは、少なくともＴＰＣビットとパイロット信号とを有するスロットを含むものであり、又ＨＳ－ＳＣＣＨ（Ｓｈａｒｅｄ　Ｃｏｎｔｒｏｌ　Ｐｈｙｓｉｃａｌ　Ｃｈａｎｎｅｌ）（下りパケット制御チャネル）と、ＨＳ－ＰＤＳＣＨ（Ｈｉｇｈ　Ｓｐｅｅｄ　Ｄｏｗｎｌｉｎｋ　Ｓｈａｒｅｄ　Ｃｈａｎｎｅｌ）（下りトラフィックチャネル）と、上りＡｃｋ，Ｎａｃｋ送信（送信チャネルは、ＨＳ－ＤＰＣＣＨ）と、上りｐｉｌｏｔ（パイロット信号、送信チャネルは、ＤＰＣＨ）送信とについて示す。

【００４３】

ＴＰＣビット（送信電力制御情報）は、Ｆ－ＤＰＣＨ、ＨＳ－ＳＣＣＨを介して送信される。

Ｆ－ＤＰＣＨは、各スロット内に異なる複数の移動局宛てのＴＰＣビットを送信可能なチャネルであり、ここでは、２つの移動局宛てのＴＰＣビットが時間多重される例を示している。但し、自局宛てＴＰＣＣとして表記している、ある１つの移動局宛てのＴＰＣビットの送信周期は、２スロットであり、間に送信しないスロットを有している。また、他局宛てＴＰＣＣと表記している他の移動局宛てのＴＰＣビットの送信周期も同様に２スロットとなっているが、もちろん、移動局毎に異なる送信周期を設定してもよい。

一方、ＨＳ－ＳＣＣＨの各フレームも制御データの送信対象の移動局に対するＴＰＣビットを送信している。尚、この例では、このある１つの移動局宛てのＨＳ－ＳＣＣＨ送信だけを記載している。

【００４４】

従って、このある１つの移動局は、ＨＳ－ＳＣＣＨの受信により、ＨＳ－ＰＤＳＣＨを受信し、パケット（データ）を受信し、その受信結果をＡＣＫ、ＮＡＣＫ信号等の応答信号としてＨＳ－ＤＰＣＣＨを介して送信する。尚、この例では、ＨＳ－ＰＤＳＣＨを３回受信することとなるが、受信処理遅延等を考慮した所定時間後に順にＡＣＫ信号、ＮＡＣ

Ｋ信号が送信されている。
　又パイロット信号は、Ｆ－ＤＰＣＨによる自局宛ての第１の送信電力制御情報ＴＰＣＣの送信周期に従って送信すると共に、ＨＳ－ＳＣＣＨを介して送信される制御情報や、Ａｃｋ，Ｎａｃｋ送信に連動して送信する。
　但し、パイロット信号は、自局宛ての第１の送信電力制御情報ＴＰＣＣの送信周期に従って、且つその送信タイミングより前のタイミングで送信する。尚、このような制御は、例えば、図２に示す無線通信装置の拡散部４６にパイロットシンボルを入力するタイミングを、図示を省略している制御部によって行うことができる。
　即ち、自局宛てにＴＰＣＣが定期的に送信されるが、その送信の際に含めるべき送信電力制御を生成するためには、移動局から既知信号（パイロット信号）が送信される必要がある。従って、自局宛てのＴＰＣＣの送信に先行して（ＴＰＣビットの生成に間に合うように所定時間前に）既知信号を送信するのである。
【００４５】
　又パイロット信号は、ＨＳ－ＳＣＣＨを介して送信される制御情報や、Ａｃｋ，Ｎａｃｋ送信に連動しても送信する。
　即ち、ＨＳ－ＳＣＣＨにより自局宛てにデータが送信されることを認識した場合、又は、ＨＳ－ＰＤＳＣＨにより自局宛てのデータを受信した場合、ＡＣＫ信号、ＮＡＣＫ信号を送信する場合に、既知信号を送信するのである。
　尚、ＨＳ－ＰＤＳＣＨの受信、ＡＣＫ信号、ＮＡＣＫ信号の送信は、結局ＨＳ－ＳＣＣＨの受信に連動して行われるため、いずれの場合であっても、結局、自局宛てのＨＳ－ＳＣＣＨの受信に連動して既知信号を送信しているといえる。
【００４６】
　従って、基地局側の図１に示す無線通信装置は、パイロット信号を受信して、ＳＩＲ推定部２５によりＳＩＲを推定し、その推定結果に基づいて、ＴＰＣＣ生成部２６に於いて送信電力制御情報ＴＰＣＣを生成し、第１の送信電力制御情報ＴＰＣＣを、Ｆ－ＤＰＣＨのスロット内の斜線を施して示す比較的長い周期（ある１つの移動局用の送信周期）で送信し、又パケット送信時は、ＨＳ－ＳＣＣＨの斜線を施して示す短い周期となる第２の送信電力制御情報ＴＰＣＣを送信する。この場合、パイロット信号を連続的に送信しなくても、送信電力制御が可能となり、従って、パイロット信号の送信に要する電力を削減することができる。又ＨＳ－ＰＤＳＣＨによりデータが送信される場合は、第１の送信電力制御情報ＴＰＣＣの送信周期をまたずとも、その送信直前のＨＳ－ＳＣＣＨによる送信電力制御情報ＴＰＣＣによってＡＣＫ信号等の送信電力制御を行うことができるから、ＳＩＲ等の無線伝播路の伝送品質に対応して、迅速に送信電力を制御することができる。
【００４７】
　又自局宛てのＨＳ－ＳＣＣＨの受信に連動して、第１の送信電力制御情報ＴＰＣＣの送信周期よりも短い周期で所定数、所定長のパイロット信号を送信するようにすると好適である。即ち、自局宛てにデータが送信されたということは、まだ残りのデータがある可能性が高く、送信スケジュールの状況にもよるが、次のデータ送信に備えることができるからである。
【００４８】
　又ＨＳ－ＳＣＣＨに連動したパイロット送信以外のパイロット送信について、Ｆ－ＤＰＣＨによる第１の送信電力制御情報ＴＰＣＣの送信周期よりも、パイロット信号の送信周期を短くすることができる。即ち、パイロット信号を受信処理してＳＩＲ推定を行う場合、パイロット信号が少ないよりも多い方が、推定精度が向上する。しかし、その分、パイロット信号送信の為の電力を必要とすることになる。そこで、前述のように、比較的長い周期で第１の送信電力制御情報を送信するが、その周期より短い周期でパイロット信号を送信して、推定精度の低下を避けることができる。
【００４９】
　又送信電力制御情報を、前述のように、Ｆ－ＤＰＣＨにより送信する第１の送信電力制御情報ＴＰＣＣ１と、ＨＳ－ＳＣＣＨにより送信する第２の送信電力制御情報ＴＰＣＣ２

とを、異なる送信電力制御量を示す情報とすることができる。その場合に、ＴＰＣＣ１＜ＴＰＣＣ２の関係とし、例えば、Ａｃｋ，Ｎａｃｋ等を送信する場合に、既に受信したＨＳ－ＳＣＣＨによる第２の送信電力制御情報ＴＰＣＣ２を利用して、所望の送信電力となるように迅速に電力上昇制御をすることができる。

尚、左から１番目のＨＳ－ＳＣＣＨのＴＰＣビットは、直前に受信したパイロット信号（この場合左から２番目のパイロット信号）に基づいて生成（または、安全のため送信電力を上げる指示とする）することとなるが、左から３つ目のパイロット信号を受信した基地局は、左から２つ目のＨＳ－ＳＣＣＨ内のＴＰＣビットをこのパイロット信号を用いて生成できる為、最初のＡＣＫ信号の送信の際に適正に送信電力制御を行うことができる。

【００５０】

又左から２番目と３番目のＨＳ－ＳＣＣＨの送信は間が離れているが、ＨＳ－ＳＣＣＨに連動したパイロット信号の送信を所定長、所定回行うようにしているので、第１の送信電力制御情報ＴＰＣＣ１の送信周期より密な周期で送信されたパイロット信号を待ってＴＰＣビット（左から６番目のパイロットを左から３番目のＨＳ－ＳＣＣＨのＴＰＣビット）に反映させることができる。尚、好ましくは、基地局は、各移動局あての第１送信電力制御情報ＴＰＣＣ１の送信タイミングを認識している為、送信周期より短い時間である時間Ｔを定義して記憶し、ある移動局についてＴＰＣＣ１の送信タイミングから時間Ｔ経過する前に、その移動局宛てにＨＳ－ＳＣＣＨやＨＳ－ＰＤＳＣＨの送信するようにすることが望ましい。

【００５１】

即ち、ＨＳ－ＰＤＳＣＨは共有チャネルであり、他の移動局宛てのデータも送信できるが、ＴＰＣＣ１からあまり時間のたっていない移動局に対するデータの送信を優先するのである。尚、この法則を適用すれば、ＨＳ－ＳＣＣＨに送信電力制御情報を含めなくとも送信電力制御が効果的に行われるが、最初のＨＳ－ＳＣＣＨ（前回のＨＳ－ＳＣＣＨの送信からＴＰＣＣ１の送信周期以上離れた最初のＨＳ－ＳＣＣＨ等）については、この法則を適用し、送信電力制御情報を省略し、ＴＰＣＣ１の送信周期以上離れていない次のＨＳ－ＳＣＣＨについては、送信電力制御情報を含めるといったこともできる。

【００５２】

即ち、最初のＨＳ－ＳＣＣＨの受信により、移動局のパイロット信号の送信が粗から密となり、合わせて送信電力制御も密に行えることとなるからである。又図４では、上りパイロットの送信タイミングをＡＣＫ信号、ＮＡＣＫ信号の送信タイミングに合わせている部分があるが、これは、上り信号を送信するのであれば、ＡＣＫ信号、ＮＡＣＫ信号、パイロット信号を同時に送信してしまう方が効率がよいからである。従って、ＨＳ－ＳＣＣＨに連動して送信するパイロット信号の送信タイミングをＡＣＫ信号、ＮＡＣｋ信号の送信タイミングに合わせることも効率を良くする一つの案である。勿論、同期させなくともよい。

【００５３】

又本発明は、前述のＷ－ＣＤＭＡ方式やＯＦＤＭ方式の無線通信方式のみでなく、他の各種の無線通信方式を適用した場合の無線通信装置及び移動無線通信システムにも適用することができるものである。

【図面の簡単な説明】

【００５４】

【図１】本発明の実施例１の説明図である。
【図２】本発明の実施例１の説明図である。
【図３】本発明の実施例１の送信電力制御の説明図である。
【図４】本発明の実施例２の送信電力制御の説明図である。
【図５】移動無線通信システムの説明図である。
【図６】ＨＳＤＰＡに於けるチャネル構成説明図である。

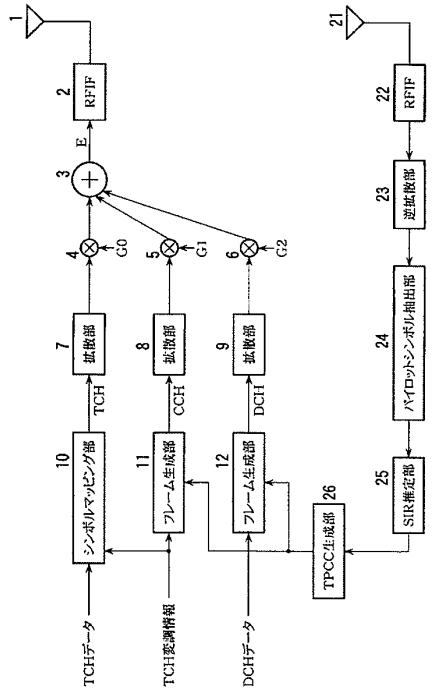
【符号の説明】

【００５５】

１，２１　アンテナ
２，２２　高周波処理部（ＲＦＩＦ）
３　多重化部
４，５，６　乗算部
７，８，９　拡散部
１０　シンボルマッピング部
１１，１２　フレーム生成部
２３　逆拡散部
２４　パイロットシンボル抽出部
２５　ＳＩＲ推定部
２６　ＴＰＣＣ生成部
３１，４１　アンテナ
３２，４２　高周波処理部（ＲＦＩＦ）
３３　ＣＣＨ逆拡散部
３４　ＴＣＨ逆拡散部
３５　ＤＣＨ逆拡散部
３６　ビット判定部
３７　ＴＰＣＣ抽出部
３８　送信電力制御部
４３　乗算部
４４　多重化部
４５，４６，４７　拡散部

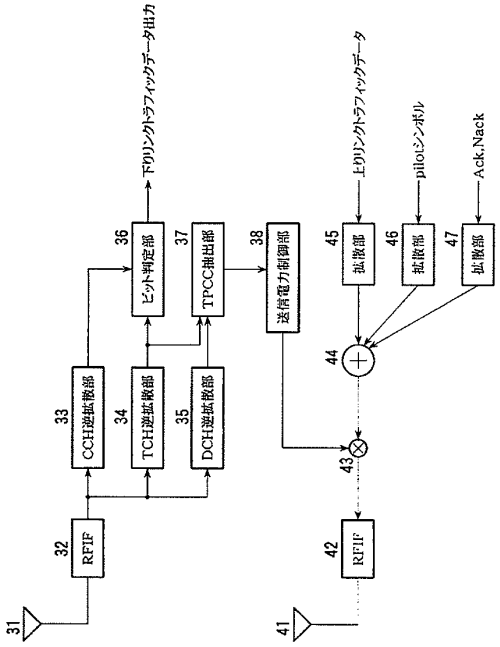
【図１】

本発明の実施例１の説明図



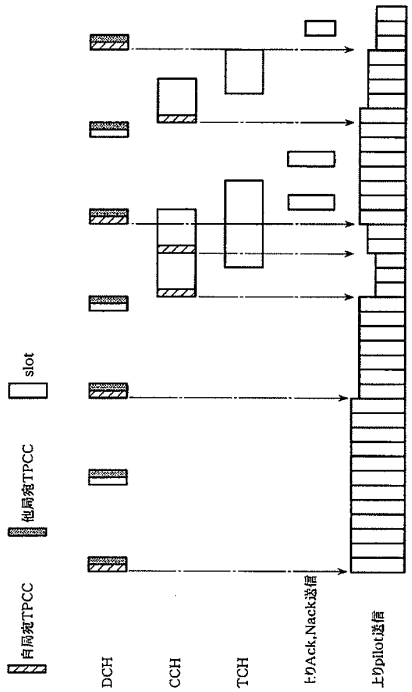
【図２】

本発明の実施例１の説明図



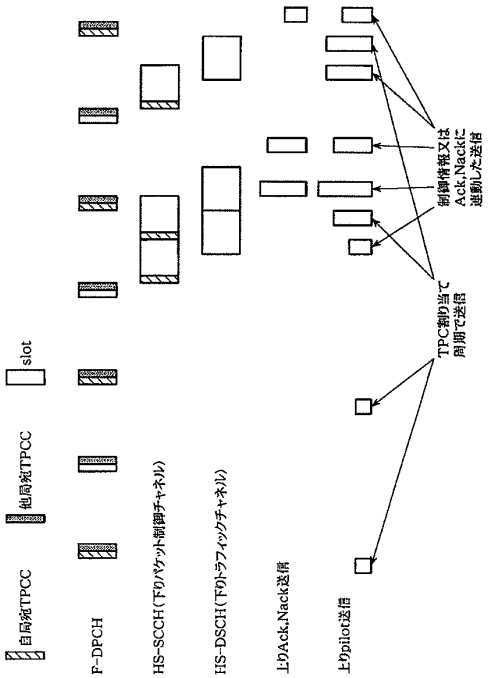
【図３】

本発明の実施例１の送信電力制御の説明図



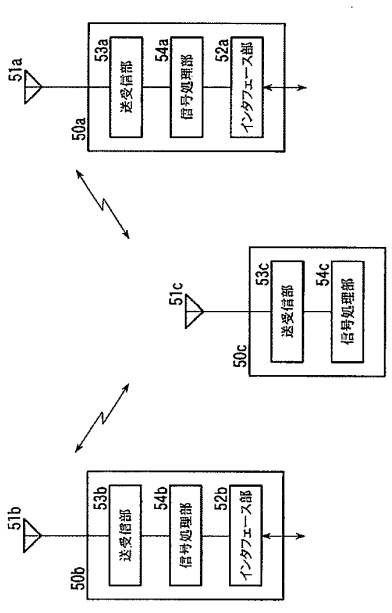
【図４】

本発明の実施例２の送信電力制御の説明図



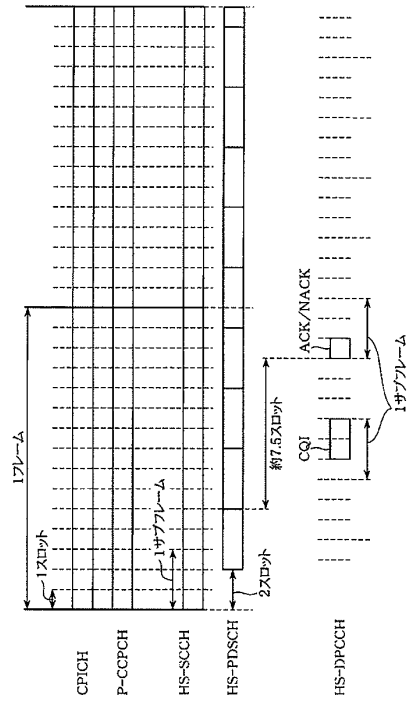
【図５】

移動無線通信システムの説明図



【図６】

ＨＳＤＰＡに於けるチャネル構成説明図



フロントページの続き

Fターム(参考) 5K022 EE02 EE21
5K067 AA43 BB04 BB21 CC08 DD27 EE02 EE10 GG04 GG08

Electronic Acknowledgement Receipt

EFS ID:	14903835
Application Number:	13176298
International Application Number:	
Confirmation Number:	4342
Title of Invention:	Feedback Control in an FDD TDD-CDMA System
First Named Inventor/Applicant Name:	Paul Howard
Customer Number:	3624
Filer:	John Porrazza/Carey Kulp
Filer Authorized By:	John Porrazza
Attorney Docket Number:	IPW2-USCN191712
Receipt Date:	07-FEB-2013
Filing Date:	05-JUL-2011
Time Stamp:	15:25:21
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	JPOA.pdf	118976 d96f0ace5b2d38227f6a28601056c8ff9e0a9cc5	no	3

Warnings:	
Information:	

2	Foreign Reference	wo06019263.pdf	1189228 4e14366c458e8fd7a08dcba6ec5f2fbbc3ce76af	no	43
Warnings:					
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3	Information Disclosure Statement (IDS) Form (SB08)	1712.pdf	1145777 8c2f9e4c6b82a126cf85dd68d7d24ddfe8cad0e4	no	4
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5	Foreign Reference	JP2006197318.pdf	1101857 95f4beb97e9fc281d1cca27f9a6083e02f5a116e	no	17
Warnings:					
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			Total Files Size (in bytes):	5639412	

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

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 February 2006 (23.02.2006)

PCT

(10) International Publication Number
WO 2006/019263 A2

(51) International Patent Classification:
H04B 7/06 (2006.01)

(21) International Application Number:
PCT/KR2005/002703

(22) International Filing Date: 17 August 2005 (17.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2004-0064553 17 August 2004 (17.08.2004) KR
10-2004-0064542 17 August 2004 (17.08.2004) KR

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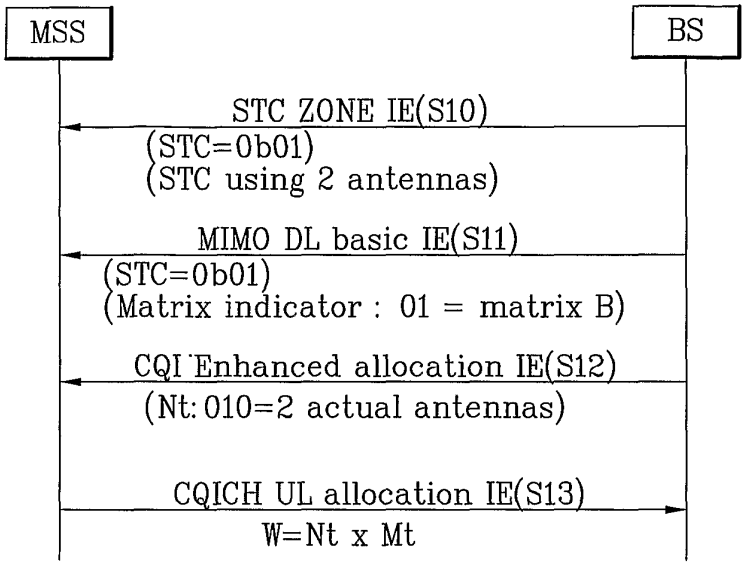
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: A METHOD FOR ESTABLISHING FAST FEEDBACK CHANNEL AND TRANSMITTING INFORMATION IN A WIRELESS COMMUNICATION SYSTEM



(57) Abstract: A method of transmitting information in a wireless communication system is disclosed. More specifically, the method includes a base station (BS) which receives data from a mobile subscriber station (MSS) via an uplink channel. Using the received data, the BS determines quality of the uplink channel. Thereafter, the BS transmits feedback information to the MSS. Here, the feedback information is based on the determined quality of the uplink channel.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

[DESCRIPTION]

A METHOD FOR ESTABLISHING FAST FEEDBACK CHANNEL AND TRANSMITTING INFORMATION IN A WIRELESS COMMUNICATION SYSTEM

Technical Field

The present invention relates to a method of establishing feedback channel and transmitting information, and more particularly, to a method of establishing fast feedback channel and transmitting information in a wireless communication system having multiple antennas.

Background Art

In an Orthogonal Frequency Division Multiplexing/Orthogonal Frequency Division Multiplexing Access (OFDM/OFDMA) system, a base station (BS), which supports a plurality of antennas, can attain transmission diversity gain by receiving feedback information from a mobile subscriber station (MSS). The feedback information includes weight value(s) or channel information. Here, the feedback information is transmitted from the MSS to the BS via an uplink transmission high speed (or fast) feedback channel.

In detail, the feedback information relates to various determined (or measured) information of the BS

transmission signals. The feedback information provides necessary information for the BS to transmit more accurate transmission signals. Here, the determined information can include various determined value(s) of downlink transmission signals. For example, the determined value of the downlink signal can be a signal/noise (S/N) value or a weight or selected mode value (space-time transmit diversity or spatial multiplexing) in case of multi-input multi-output (MIMO).

Figure 1 illustrates an example of a MSS sending to a BS feedback information, which includes weight values (or channel information), acquired in a downlink transmission. As illustrated in Figure 1, the BS, which uses a plurality of antennas, informs the MSS of a space-time coding (STC) mode via a STC zone IE message. The STC mode is determined based on a number of antennas possessed by the BS. At the same time, the BS notifies the MSS which matrix type (e.g., type B) the BS plans to use. The multi-input multi-output (MIMO) downlink (DL) basic IE message is the avenue through which the BS notifies the MSS of which matrix type it plans to use. Furthermore, the BS notifies to the MSS via a Channel Quality Indicator Channel (CQICH) Enhanced Allocation IE message the mapping scheme of the weight value to be assigned to the uplink high speed feedback channel.

On the other hand, the MSS determines the downlink channel quality or acquires a weight matrix W based on the downlink channel quality determination. The size of the weight matrix is determined by the number of BS transmission antennas and the number of output signals according to the STC scheme. The following Equation 1 is an example of the weight matrix W in connection with four BS transmission antennas and two STC outputs.

[Equation 1]

$$W = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \\ w_{31} & w_{32} \\ w_{41} & w_{42} \end{bmatrix}$$

The MSS sends feedback of the weight matrix W and the channel quality information acquired through Equation 1 via the CQICH (S12). In order to improve the signal-to-noise ratio (SNR) in the receiving end by the BS, which uses a plurality of transmission antennas, the BS receives a downlink determined value or a weight value. At the same time, the BS allocates the uplink CQICH to the MSS in order to receive the downlink determined value or weight value.

Additionally, in the existing 802.16 OFDMA system, a message of the fast feedback channel of the uplink is allocated to an uplink slot. Here, an uplink slot

indicates one sub-channel zone, which encompasses three symbols, and is comprised of six tiles. A slot of IEEE 802.16 OFDMA system refers to the smallest unit available for data allocation and can be expressed in time domain and sub-channel domain. Moreover, a tile comprises eight data sub-carriers.

Table 1 provided below shows a method by which sub-carriers of a fast feedback channel are modulated. Moreover, Table 2 shows sub-carrier modulation method as applied to each vector of Table 1.

[Table 1]

4 bit payload	Vector indices to be used by fast feedback channel per tile (tile 0, tile 1… tile 5)
0b0000	0,0,0,0,0,0
0b0001	1,1,1,1,1,1
0b0010	2,2,2,2,2,2
0b0011	3,3,3,3,3,3
0b0100	4,4,4,4,4,4
0b0101	5,5,5,5,5,5
0b0110	6,6,6,6,6,6
0b0111	7,7,7,7,7,7
0b1000	0,1,2,3,4,5
0b1001	1,2,3,4,5,6
0b1010	2,3,4,5,6,7
0b1011	3,4,5,6,7,0
0b1100	4,5,6,7,0,1

0b1101	5,6,7,0,1,2
0b1110	6,7,0,1,2,3
0b1111	7,0,1,2,3,4

[Table 2]

Vector Index	Data sub-carrier modulation method per each vector index (sub-carrier 0, sub-carrier 1 … sub-carrier 7)
0	P0, P1, P2, P3, P0, P1, P2, P3
1	P0, P3, P2, P1, P0, P3, P2, P1
2	P0, P0, P1, P1, P2, P2, P3, P3
3	P0, P0, P3, P3, P2, P2, P1, P1
4	P0, P0, P0, P0, P0, P0, P0, P0
5	P0, P2, P0, P2, P0, P2, P0, P2
6	P0, P2, P0, P2, P2, P0, P2, P0
7	P0, P2, P2, P0, P2, P0, P0, P2

As shown in Table 1 and Table 2, the feedback information is expressed as payload in four (4) bits, and based the payload value, vector indices of six (6) tiles to be used in the fast feedback channel can be attained. Furthermore, eight (8) sub-carriers are provided with different modulation values based on each vector index.

The following are equations regarding each modulation scheme (P0, P1, P2, P3) with respect to Table 2.

$$P0 = \frac{1}{\sqrt{2}} \cdot \exp\left(j \cdot \frac{\pi}{4}\right)$$
$$P1 = \frac{1}{\sqrt{2}} \cdot \exp\left(j \cdot \frac{3\pi}{4}\right)$$
$$P2 = \frac{1}{\sqrt{2}} \cdot \exp\left(-j \cdot \frac{3\pi}{4}\right)$$
$$P3 = \frac{1}{\sqrt{2}} \cdot \exp\left(-j \cdot \frac{\pi}{4}\right)$$

The MSS using a plurality of antennas has to receive feedback information from the BS in order to achieve transmission diversity. The feedback information includes the uplink determined value (channel information or weight value). However, there is not a defined channel which allows for fast feedback of the BS determined value to the MSS.

Disclosure of Invention

Accordingly, the present invention is directed to a [title] that substantially obviates one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a method of transmitting information in a wireless communication system.

Another object of the present invention is to provide a method of receiving information in a wireless communication system.

A further object of the present invention is to provide a

wireless communication system for transmitting information.

Another object of the present invention is to provide a method of establishing a fast feedback channel and transmitting information thereto.

Another object of the present invention is to provide a method of receiving transmitted information through an established fast feedback channel.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objectives and other advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a method of transmitting information in a wireless communication system which includes a base station (BS) which receives data from a mobile subscriber station (MSS) via an uplink channel. Using the received data, the BS determines quality of the uplink channel. Thereafter, the BS transmits feedback information to the MSS. Here, the feedback information is

based on the determined quality of the uplink channel.

In another aspect of the present invention, a method of transmitting information in a wireless communication system which includes a base station (BS) which allocates a physical resource for a downlink fast feedback channel. Here, the physical resource for the downlink fast feedback channel is different from a physical resource for a data channel. Furthermore, the BS establishes a modulation pattern, which corresponds to feedback information, to the downlink fast feedback channel by the BS. In addition, the BS transmits the modulation pattern, which corresponds to feedback information, to a mobile subscriber station (MSS) so that the MSS can determine which feedback information is transmitted from the BS via the modulation pattern.

In another aspect of the present invention, a method of receiving information in a wireless communication system which includes a mobile subscriber station (MSS) which transmits data to a base station (BS) via an uplink channel. Thereafter, the MSS receives feedback information from the MSS. Here, the feedback information is based on quality of the uplink channel, and the quality of the uplink channel is determined based on the transmitted data.

In another aspect of the present invention, a method of receiving information in a wireless communication system which includes a mobile subscriber station (MSS) which

receives and detects a modulation pattern transmitted from a base station (BS). Here, the modulation pattern is established to a downlink fast feedback channel, and importantly, the modulation pattern corresponds to feedback information. Furthermore, the MSS determines which feedback information is transmitted from the BS via the modulation pattern. After determining which feedback information is transmitted from the BS, the MSS transmits uplink data which is configured by using the feedback information.

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

Brief Description of Drawings

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate embodiment(s) of the invention and together with the description serve to explain the principle of the invention. In the drawings;

FIG. 1 illustrates an example of a mobile subscriber station sending to a base station feedback information,

which includes weight values (or channel information), acquired in a downlink transmission;

FIG. 2 illustrates an example of the BS sending feedback information, which includes the result of uplink channel quality assessment, to the MSS in the OFDM/OFDMA system according to an embodiment of the present invention;

FIG. 3 illustrates an example of setting a determined uplink value to a specified physical resource of a fast feedback channel;

FIG. 4 illustrates an example of a format of an IE message of a downlink high speed feedback channel using an extended DIUC; and

FIG. 5 illustrates an example of a format of an IE message of a downlink high speed feedback channel using an OFDMA DIUC value;

FIG 6. is an example of a format illustrating the CQICH DL location IE message which includes the weight value and channel information of the BS;

FIG. 7 is an example of a structure of a wireless communication system illustrating an operation of transmitting/receiving information between the BS and the MSS.

FIG. 8 illustrates an example of a basic allocation unit of a fast feedback channel in a downlink Partial Usage of Sub-Channels (PUSC) mode;

FIG. 9 illustrates an example of a basic allocation unit of a fast feedback channel in a downlink Full Usage of Sub-Channels (FUSC) mode;

FIG. 10 illustrates an example of a composition of data sub-carriers; and

FIG. 11 illustrates an example of a composition of data sub-carriers.

Best Mode for Carrying Out the Invention

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. The embodiments of the present invention can apply to an Orthogonal Frequency Division Multiplexing/Orthogonal Frequency Division Multiplexing Access (OFDM/OFDMA) system and also can be applied to other standards wireless communication system. Examples related to the embodiments of the present invention are provided below.

In an embodiment of the present invention, a base station (BS) sends feedback information to a mobile subscriber station (MSS) via a fast (or high speed) downlink feedback channel. The feedback information includes a channel quality information (CQI) and weight value(s) received

through uplink channel(s). In operation, the BS informs the MSS of the fast downlink feedback channel through which data is transmitted. Thereafter, the BS establishes the CQI or weight value to the fast downlink feedback channel and transmits the information to the MSS.

Preferably, the notification of the fast downlink feedback channel to the MSS is carried out via a DIUC message or a downlink (DL) fast feedback channel IE message. Here, the CQI or the weight values are transmitted via the CQI Channel (CQICH) DL location IE message.

Figure 2 illustrates an example of the BS sending feedback information, which includes the result of uplink channel quality assessment, to the MSS in the OFDM/OFDMA system according to the embodiment of the present invention. In Figure 2, as explained above, the BS assigns the STC mode to the MSS based the number of BS transmission antennas via the STC zone IE message. At the same time, the MSS acquires weight matrix ($W=N_t \times M_t$). The weight matrix is derived based on the number of BS transmission antennas and the number of output signals from the STC scheme. Moreover, the BS allocates the uplink high speed feedback channel, also referred to as the CQICH, to the MSS.

Subsequently, the MSS notifies of the weight matrix ($W=N_t \times M_t$) to the BS via the allocated CQICH, and the BS, as a result is able to attain transmission diversity gain by