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(54) **BASE STATION, PROCESSOR, COMMUNICATION CONTROL METHOD AND USER TERMINAL**

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(57) **ABSTRACT**

A base station that communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, comprises: a control unit that changes a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals. The control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

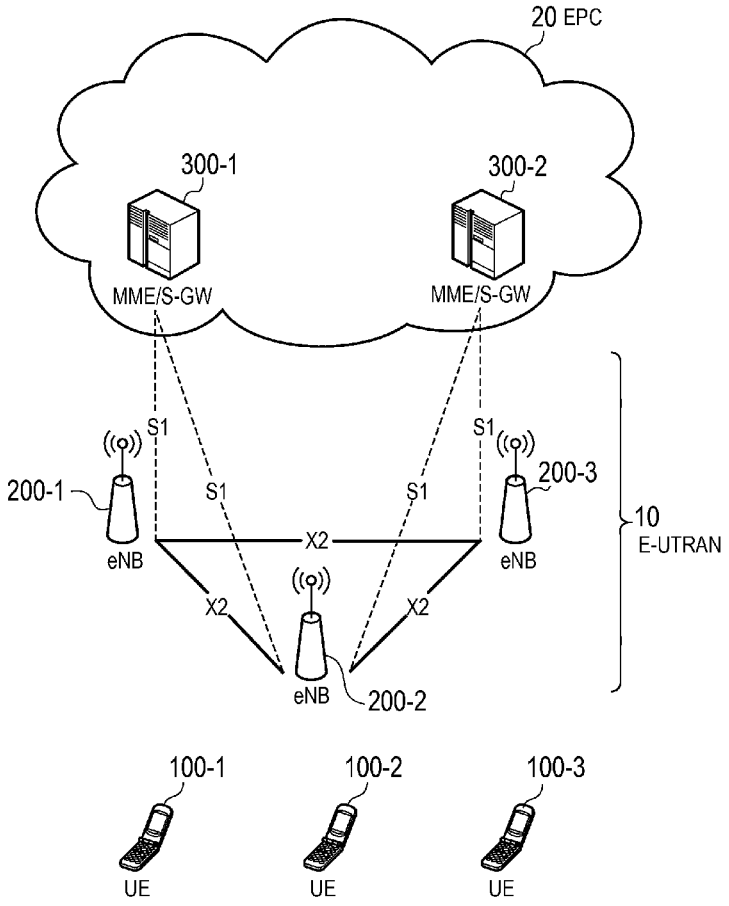


FIG. 1

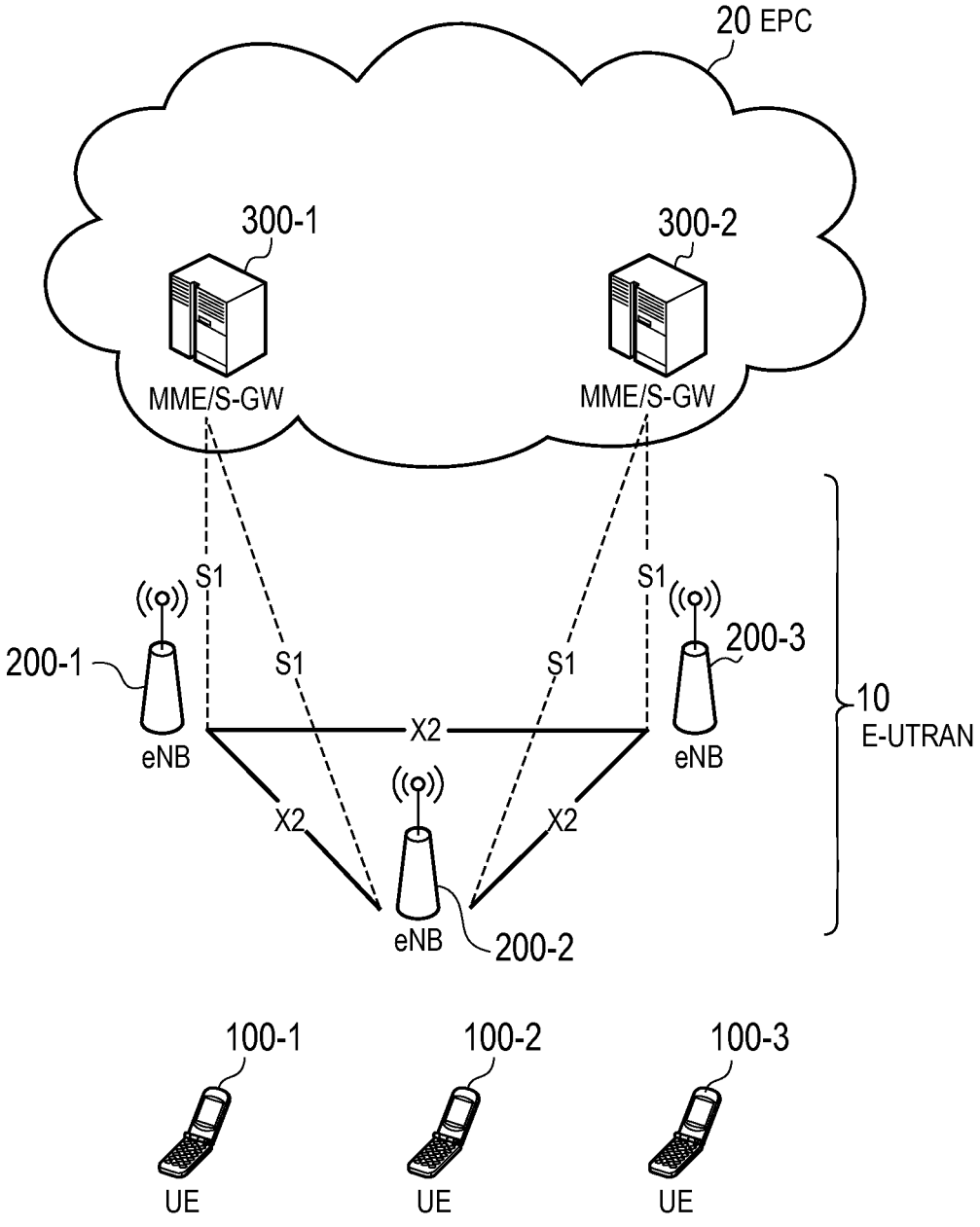

20 EPC
300-1
300-2
MME/S-GW
MME/S-GW
S1
S1
S1
S1
200-1
200-3
eNB
eNB
X2
X2
X2
10
E-UTRAN
eNB
200-2
100-1
100-2
100-3
UE
UE
UE

FIG. 2

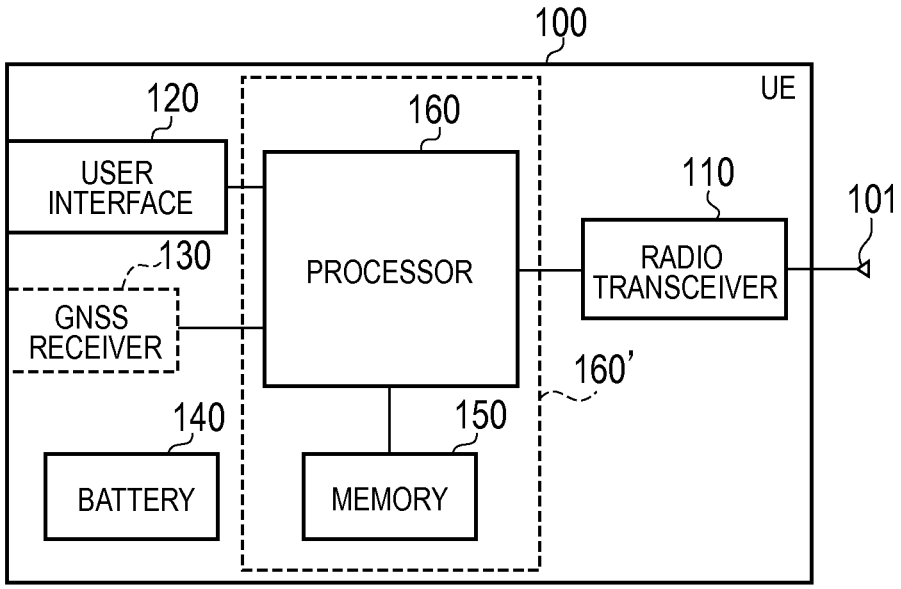

100
UE
120
USER INTERFACE
160
PROCESSOR
110
RADIO TRANSCEIVER
101
130
GNSS RECEIVER
160'
140
BATTERY
150
MEMORY

FIG. 3

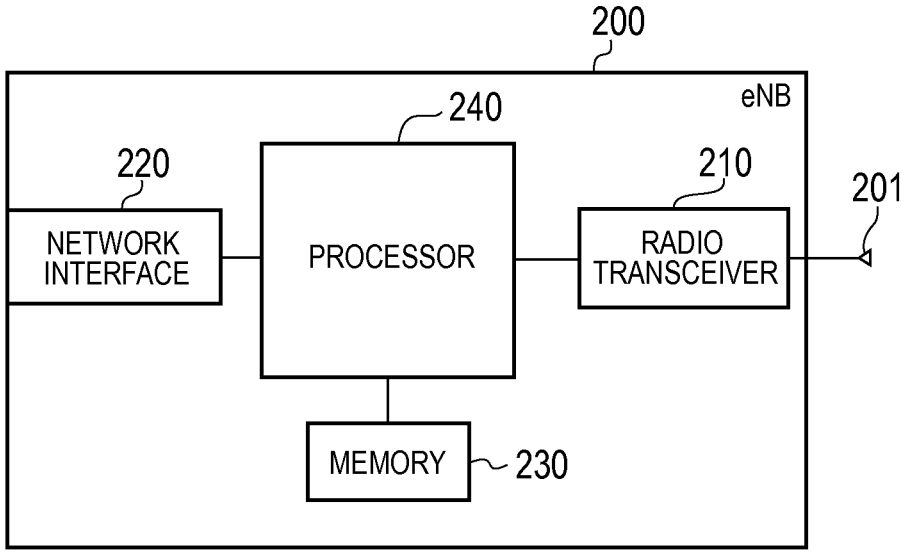

200
eNB
240
220
NETWORK INTERFACE
PROCESSOR
210
RADIO TRANSCEIVER
201
MEMORY
230

FIG. 4

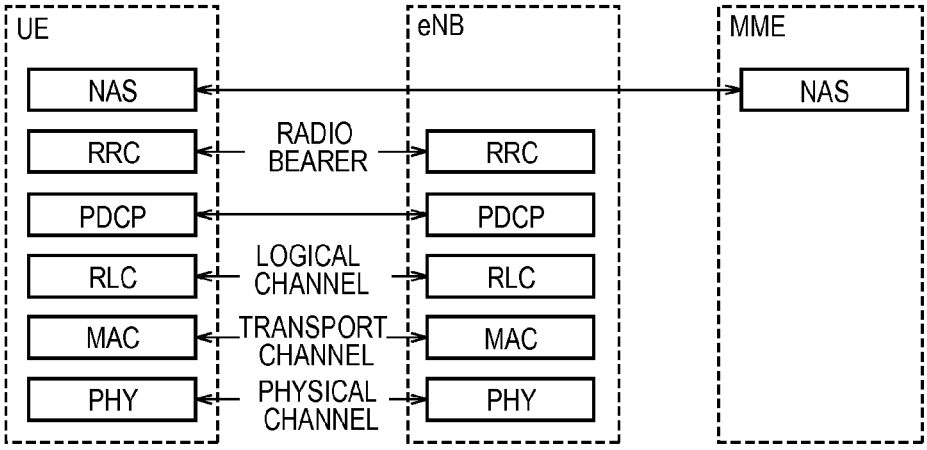

UE
eNB
MME
NAS
NAS
RRC
RADIO BEARER
RRC
PDCP
PDCP
RLC
LOGICAL CHANNEL
RLC
MAC
TRANSPORT CHANNEL
MAC
PHY
PHYSICAL CHANNEL
PHY

FIG. 5

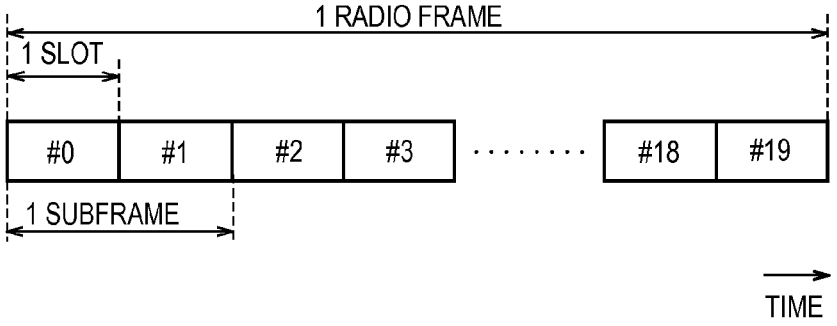

1 RADIO FRAME
1 SLOT
#0
#1
#2
#3
#18
#19
1 SUBFRAME
TIME

FIG. 6

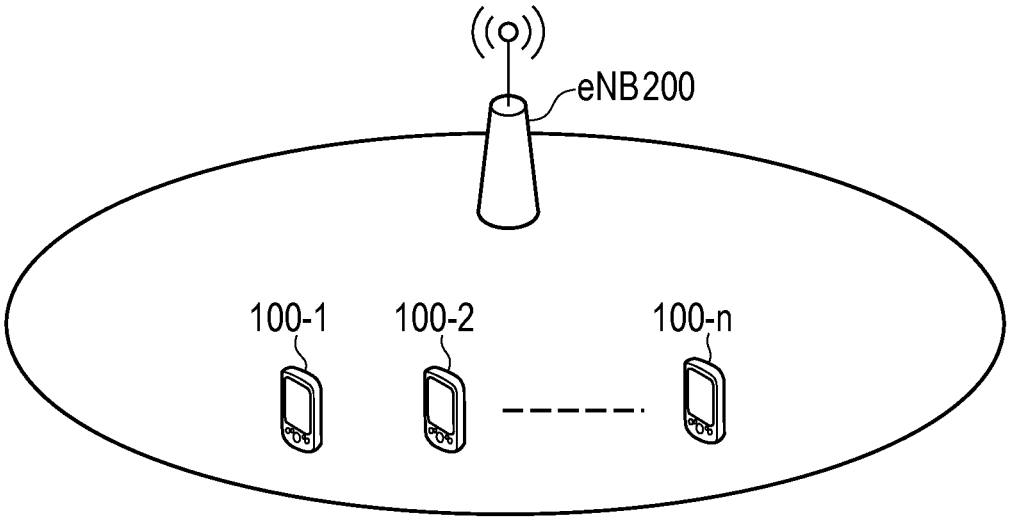


FIG. 7

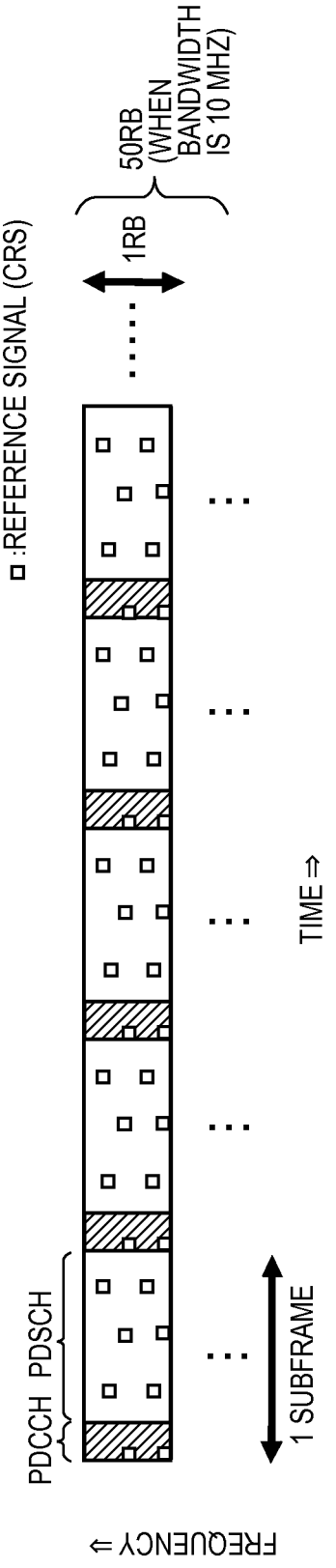

50RB (WHEN BANDWIDTH IS 10 MHZ)
1RB
:REFERENCE SIGNAL (CRS)
PDCCH
PDSCH
1 SUBFRAME
TIME ⇒
FREQUENCY ⇒

FIG. 8

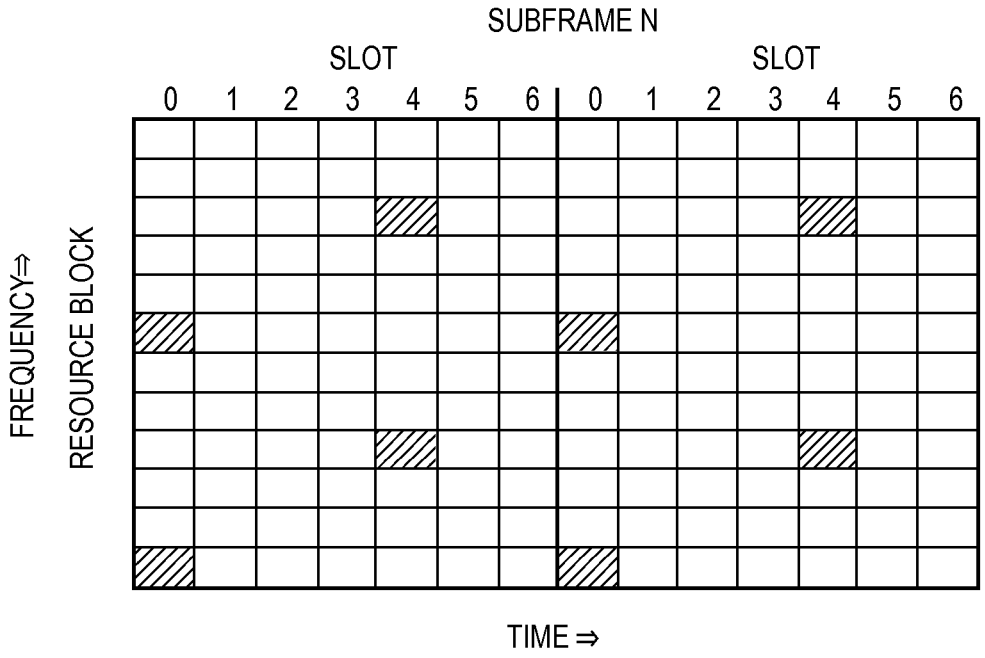

SUBFRAME N
SLOT
SLOT
0 1 2 3 4 5 6 0 1 2 3 4 5 6
FREQUENCY⇒
RESOURCE BLOCK
TIME ⇒

FIG. 9

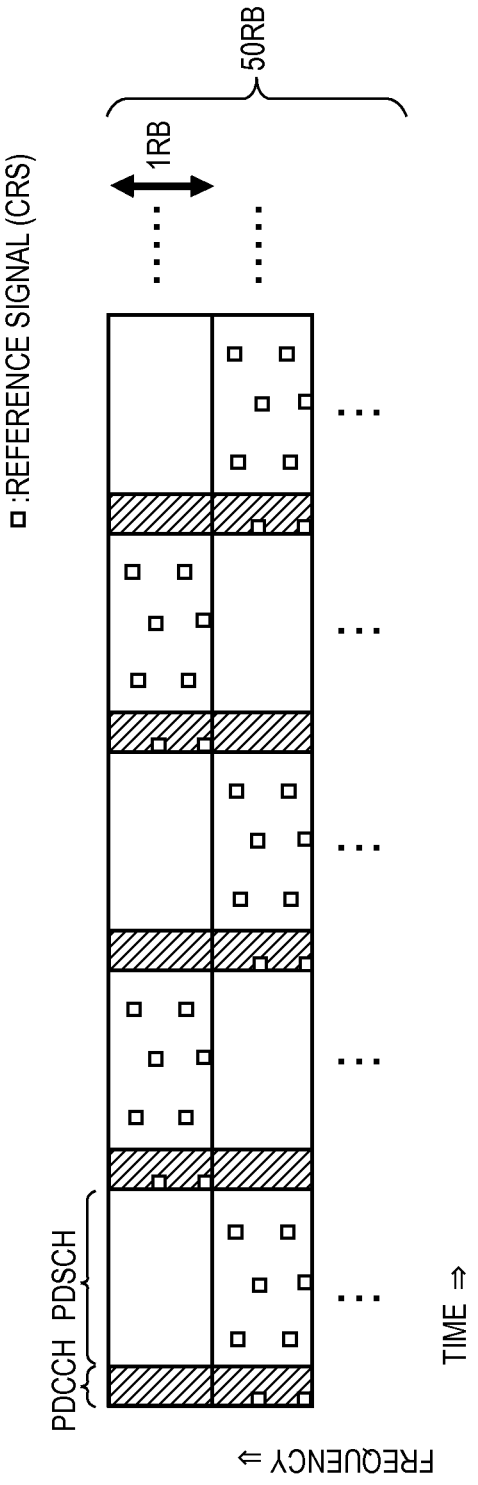


FIG. 10

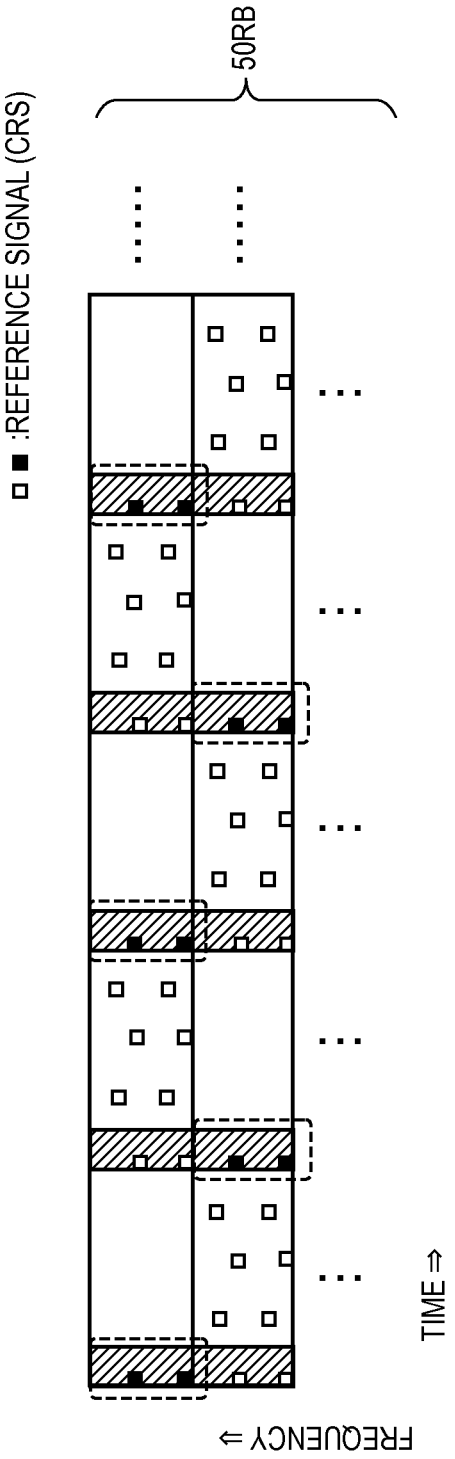


FIG. 11

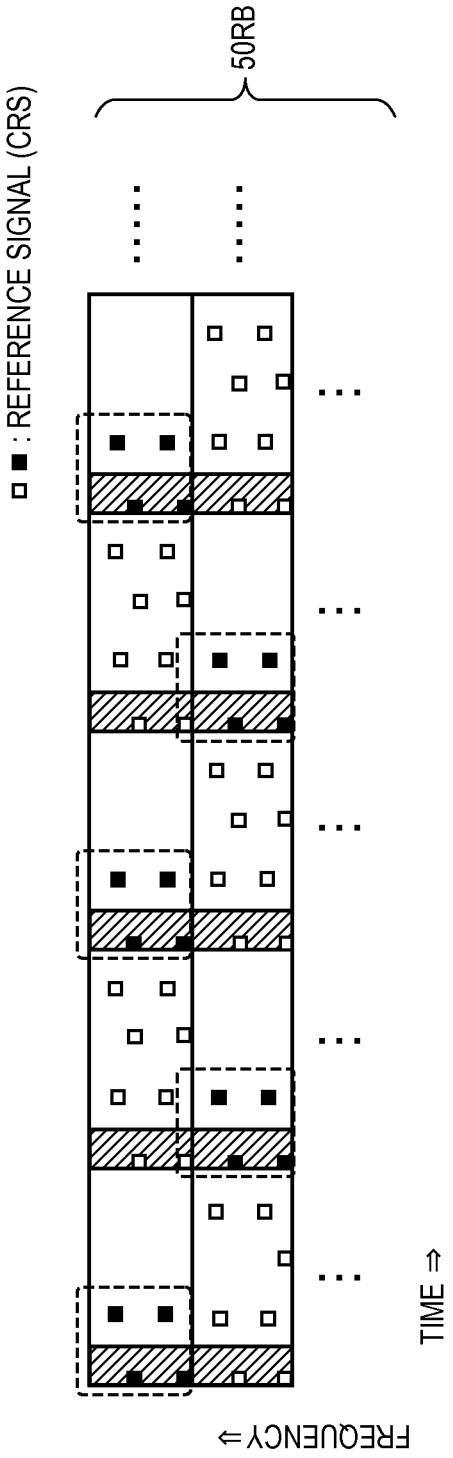


FIG. 12

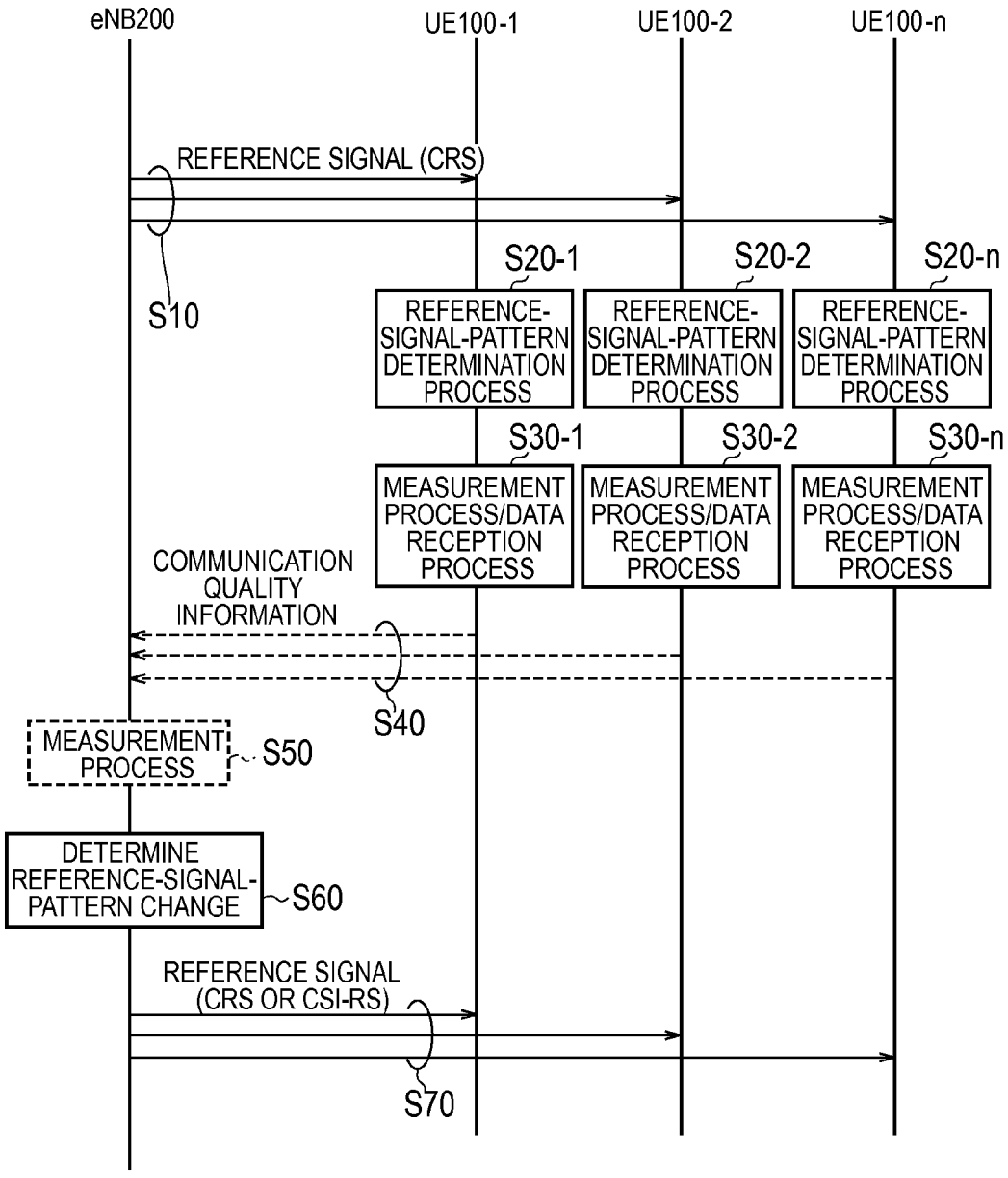

eNB200
UE100-1
UE100-2
UE100-n
REFERENCE SIGNAL (CRS)
S10
S20-1
S20-2
S20-n
REFERENCE-SIGNAL-PATTERN DETERMINATION PROCESS
REFERENCE-SIGNAL-PATTERN DETERMINATION PROCESS
REFERENCE-SIGNAL-PATTERN DETERMINATION PROCESS
S30-1
S30-2
S30-n
MEASUREMENT PROCESS/DATA RECEPTION PROCESS
MEASUREMENT PROCESS/DATA RECEPTION PROCESS
MEASUREMENT PROCESS/DATA RECEPTION PROCESS
COMMUNICATION QUALITY INFORMATION
S40
MEASUREMENT PROCESS
S50
DETERMINE REFERENCE-SIGNAL-PATTERN CHANGE
S60
REFERENCE SIGNAL (CRS OR CSI-RS)
S70

FIG. 13

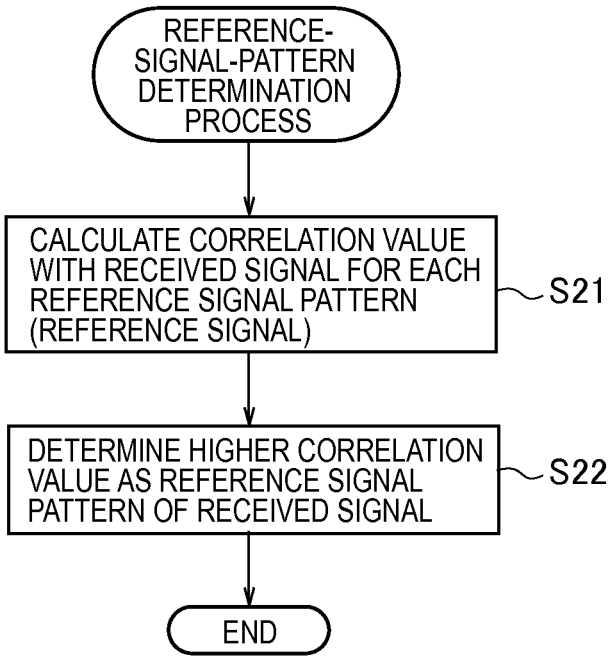

REFERENCE-SIGNAL-PATTERN DETERMINATION PROCESS
CALCULATE CORRELATION VALUE WITH RECEIVED SIGNAL FOR EACH REFERENCE SIGNAL PATTERN (REFERENCE SIGNAL)
S21
DETERMINE HIGHER CORRELATION VALUE AS REFERENCE SIGNAL PATTERN OF RECEIVED SIGNAL
S22
END

FIG. 14

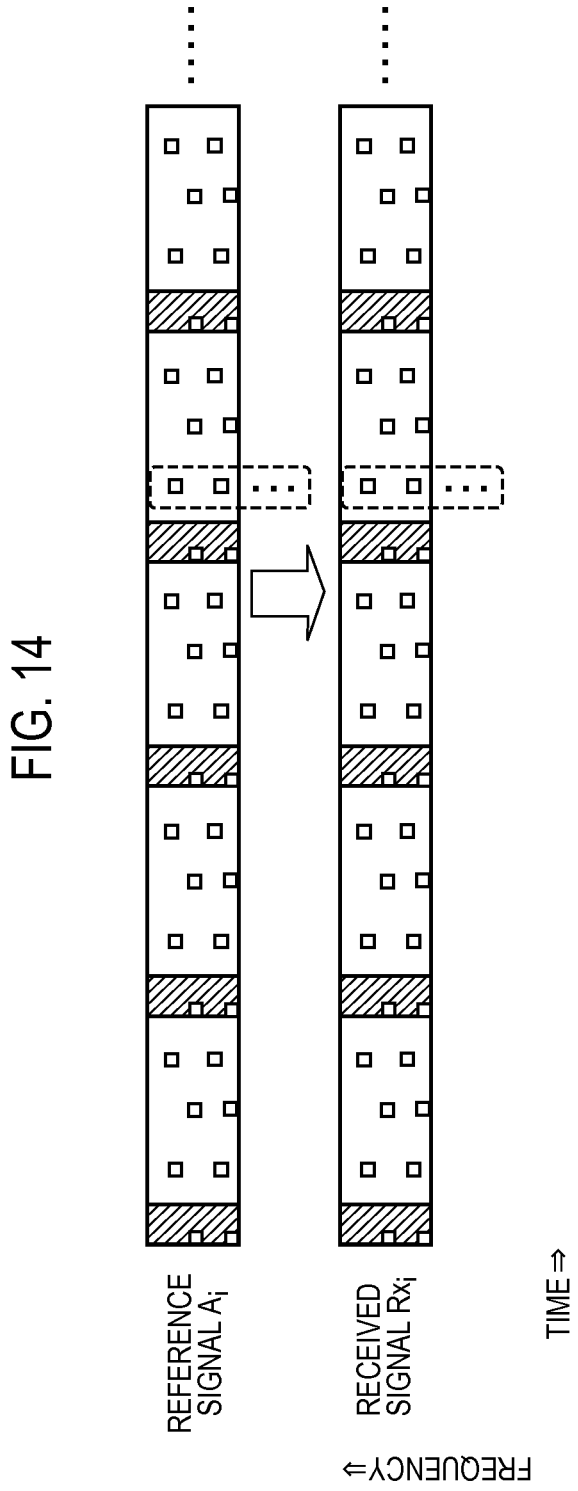


FIG. 15

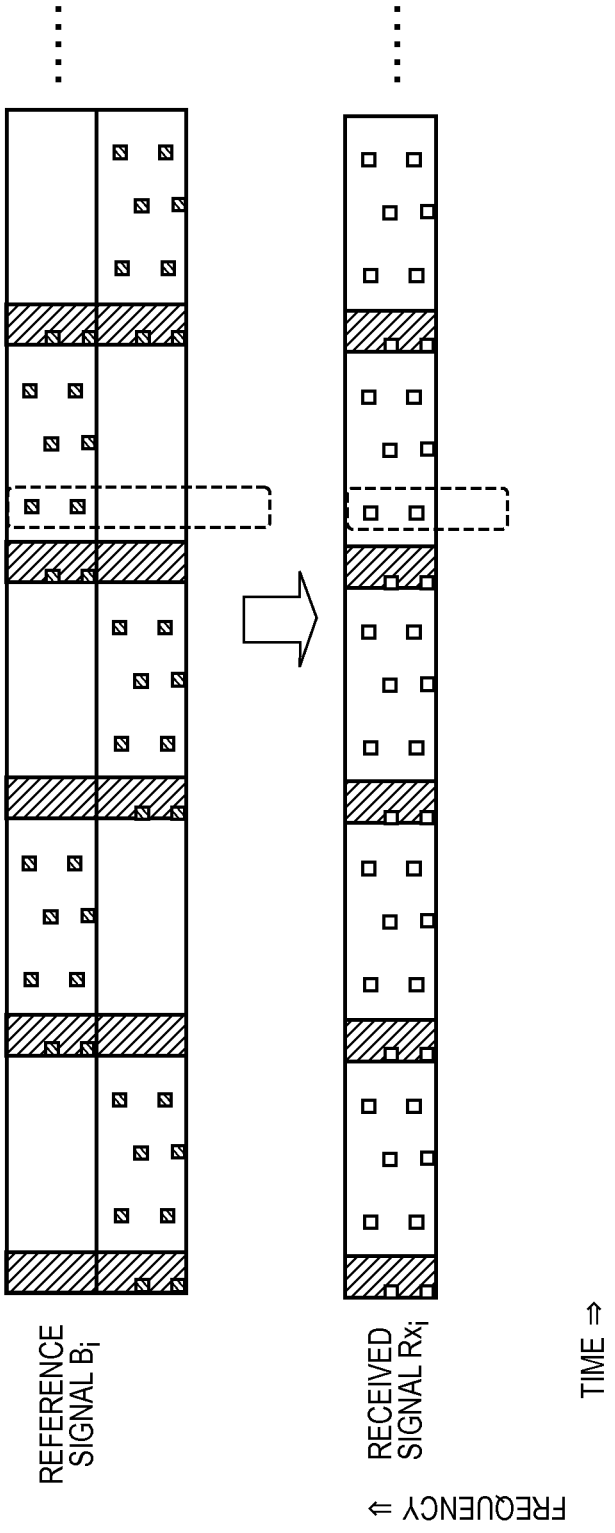


FIG. 16

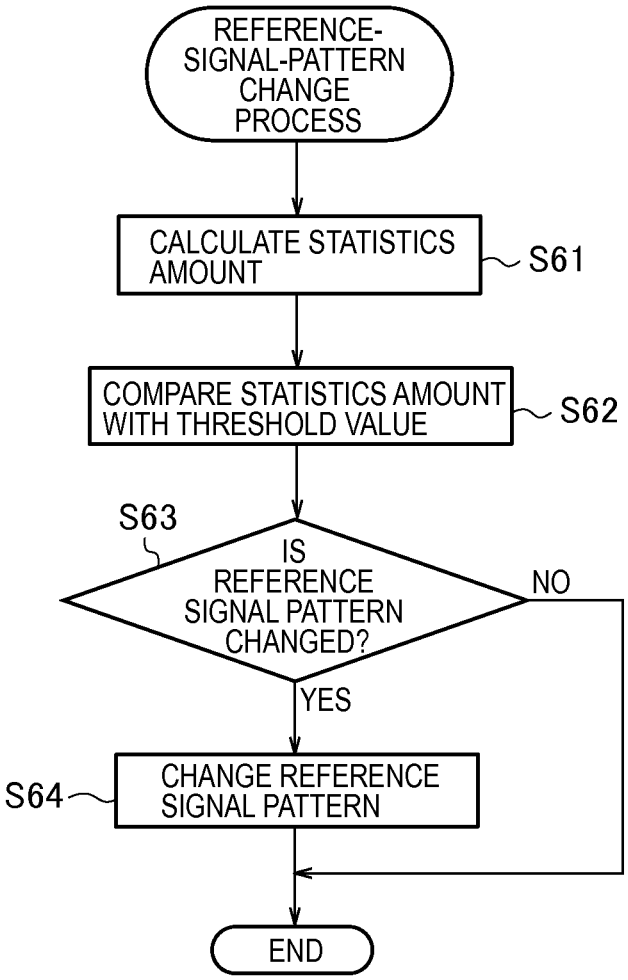

REFERENCE-SIGNAL-PATTERN CHANGE PROCESS
CALCULATE STATISTICS AMOUNT
S61
COMPARE STATISTICS AMOUNT WITH THRESHOLD VALUE
S62
S63
IS REFERENCE SIGNAL PATTERN CHANGED?
NO
YES
S64
CHANGE REFERENCE SIGNAL PATTERN
END

FIG. 17

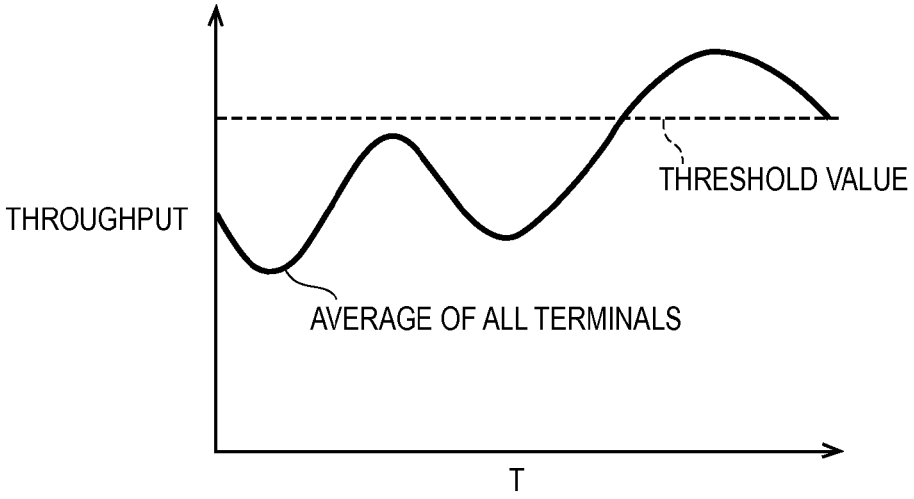

THROUGHPUT
THRESHOLD VALUE
AVERAGE OF ALL TERMINALS
T

FIG. 18

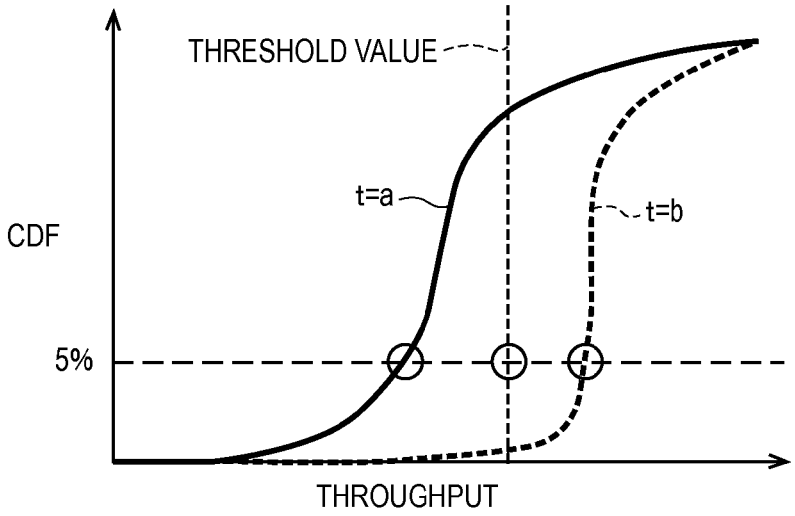

THRESHOLD VALUE
t=a
t=b
CDF
5%
THROUGHPUT

FIG. 19

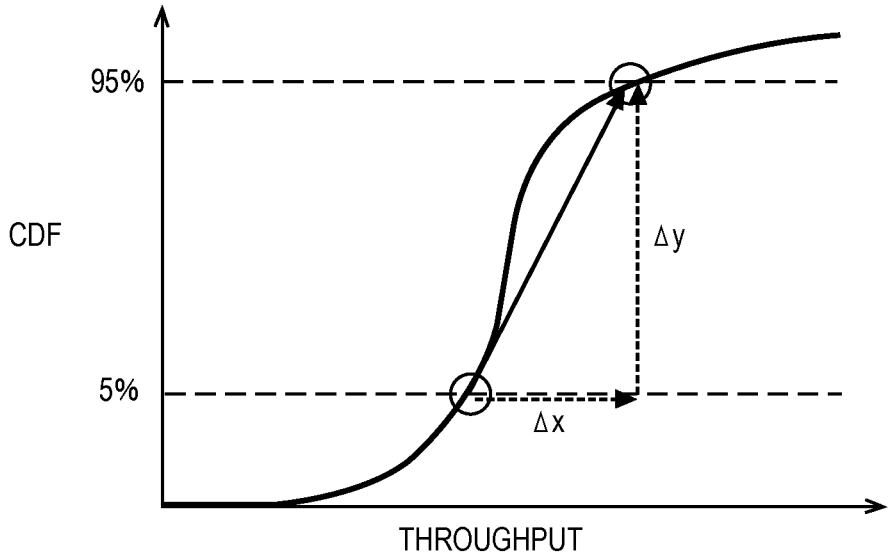


FIG. 20

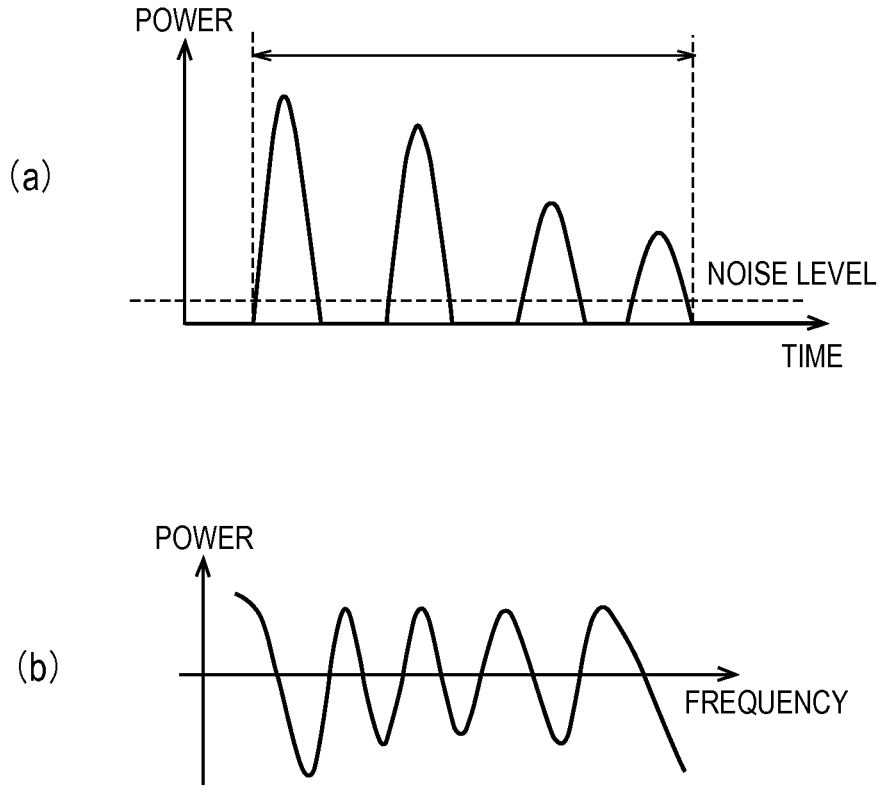
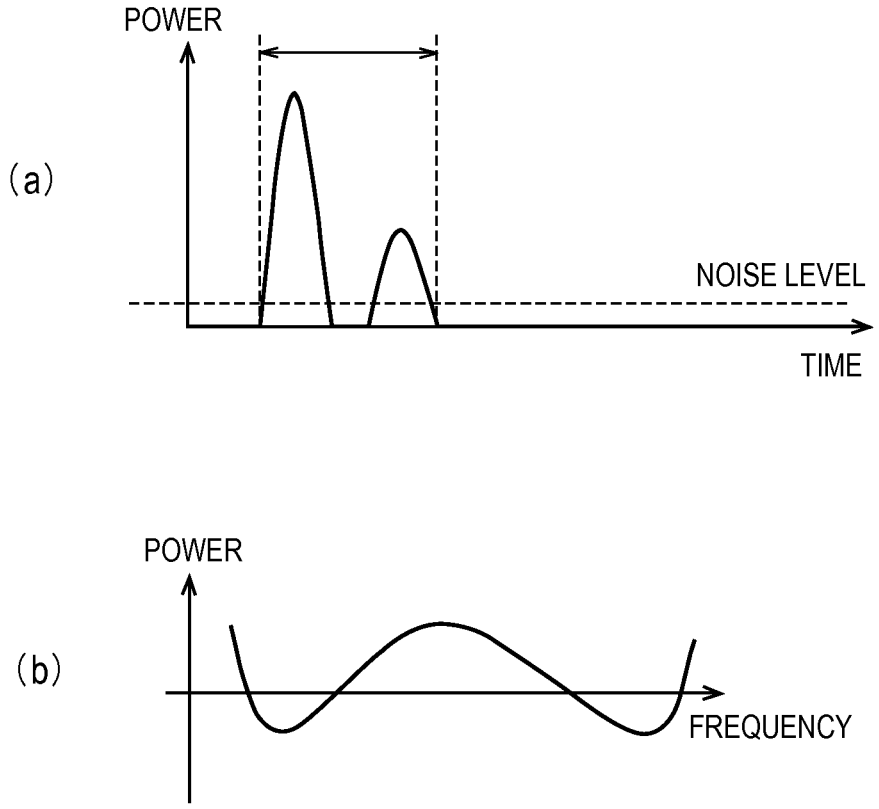


FIG. 21



BASE STATION, PROCESSOR, COMMUNICATION CONTROL METHOD AND USER TERMINAL

TECHNICAL FIELD

[0001] The prevent invention relates to a base station used in a mobile communication system in which a radio signal including a reference signal is transmitted and received, a processor therefor, a communication control method therefor, and a user terminal.

BACKGROUND ART

[0002] In 3GPP (3rd Generation Partnership Project) which is a project aiming to standardize a mobile communication system, it is considered to introduce a new carrier to which a special physical layer specification is applied in addition to a conventional carrier to which a physical layer specification up to Release 11 is applied.

[0003] As one of the new carriers, a carrier in which the density of a reference signal is more decreased than a conventional carrier is proposed (for example, see Non Patent Document 1). As a result, a radio resource used for transmitting a reference signal can be used for transmitting user data, etc., and therefore, it is possible to improve throughput.

PRIOR ART DOCUMENT

Non-Patent Document

[0004] Non-Patent Document 1: 3GPP contribution "R1-121382"

SUMMARY OF THE INVENTION

[0005] A reference signal is a signal necessary for estimating a channel characteristic (so-called channel estimation). Therefore, when the density of the reference signal is decreased, it is probable that throughput deteriorates depending on each communication environment as a result of the accuracy of the channel estimation being decreased.

[0006] Therefore, the present invention provides a base station, a processor, a communication control method, and a user terminal with which it is possible to appropriately control the density of a reference signal.

[0007] According to an embodiment, a base station that communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, comprises: a control unit that changes a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals. The control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a configuration diagram of an LTE system according to an embodiment.

[0009] FIG. **2** is a block diagram of UE according to the embodiment.

[0010] FIG. **3** is a block diagram of eNB according to the embodiment.

[0011] FIG. **4** is a protocol stack diagram of a radio interface in the LTE system.

[0012] FIG. **5** is a configuration diagram of a radio frame used in the LTE system.

[0013] FIG. **6** is a diagram illustrating an operation environment according to the embodiment.

[0014] FIG. **7** is a frame configuration diagram for explaining a reference signal pattern A according to the embodiment.

[0015] FIG. **8** is a diagram illustrating an arrangement example of a downlink reference signals in one subframe and one RB.

[0016] FIG. **9** is a frame configuration diagram for explaining a specific example 1 of a reference signal pattern B according to the embodiment.

[0017] FIG. **10** is a frame configuration diagram for explaining a specific example 2 of the reference signal pattern B according to the embodiment.

[0018] FIG. **11** is a frame configuration diagram for explaining a specific example 3 of the reference signal pattern B according to the embodiment.

[0019] FIG. **12** is an operation sequence diagram according to the embodiment.

[0020] FIG. **13** is an operation flowchart showing a detail of step S**20** in FIG. **12**.

[0021] FIG. **14** is a diagram for explaining a specific example of a reference pattern determination according to the embodiment.

[0022] FIG. **15** is a diagram for explaining a specific example of a reference signal pattern determination according to the embodiment.

[0023] FIG. **16** is an operation flowchart showing a detail of step S**60** in FIG. **12**.

[0024] FIG. **17** is a diagram showing one example of an average throughput as a statistics amount according to the embodiment.

[0025] FIG. **18** is a diagram showing one example of throughput CDF as a statistics amount according to the embodiment.

[0026] FIG. **19** is a diagram showing one example of throughput CDF as a statistics amount according to the embodiment.

[0027] FIG. **20** is a diagram showing one example of a worst value of a delay dispersion range as a statistics amount according to the embodiment.

[0028] FIG. **21** is a diagram showing one example of a worst value of a delay dispersion range as a statistics amount according to the embodiment.

DESCRIPTION OF THE EMBODIMENT

Overview of Embodiment

[0029] A base station according to an embodiment communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The base station comprises: a control unit that changes a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals. The control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

[0030] As a result, it is possible to dynamically change a reference signal density while statistically determining a

communication environment of all user terminal connected with the base station, on the basis of a statistics amount of communication quality information.

[0031] In the embodiment, the reference signal is a downlink reference signal commonly applied to the plurality of user terminals.

[0032] In the embodiment, the communication quality information is at least one of: throughput for each of the plurality of user terminals; CQI for each of the plurality of user terminals; a moving speed for each of the plurality of user terminals; and a delay dispersion range for each of the plurality of user terminals.

[0033] In the embodiment, the statistics amount is an average of the communication quality information, a worst value of the communication quality information, or a cumulative distribution function of the communication quality information.

[0034] In the embodiment, the control unit changes, when a predetermined reference signal density is used for the communication with the plurality of user terminals, the reference signal density to a reference signal density that is lower than the predetermined reference signal density, in accordance with improvement on the statistics amount.

[0035] In the embodiment, the control unit changes, when a predetermined reference signal density is used for the communication with the plurality of user terminals, the reference signal density to a reference signal density that is higher than the predetermined reference signal density, in accordance with deterioration of the statistics amount.

[0036] In the embodiment, the control unit excludes a user terminal, in which the degree of a variation of the corresponding communication quality information is greater than a threshold value, out of the plurality of user terminals, from a target for calculating the statistics amount.

[0037] In the embodiment, the control unit excludes a user terminal, in which a data amount corresponding to an application to be executed is smaller than a threshold value, out of the plurality of user terminals, from a target of calculating the statistics amount.

[0038] In the embodiment, the base station configures a small cell smaller than a macro cell, and the plurality of user terminals are connected with the small cell.

[0039] A processor according to the embodiment is provided in a base station that communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The processor performs a process for calculating a statistics amount of communication quality information acquired for all the plurality of user terminals, and changing a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals on the basis of the statistics amount.

[0040] A communication control method according to the embodiment is used in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The communication control method comprises: a step A of changing, by a base station that communicates with a plurality of user terminals, a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals. In the step A, the control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

[0041] A user terminal according to the embodiment communicates with abase station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The user terminal comprises: a storage unit that stores a plurality of reference signal patterns each having a different density of the reference signal; a reception unit that receives the radio signal including the reference signal, from the base station; and a control unit that determines a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

[0042] As a result, even when the reference signal pattern (that is, the density of the reference signal) is changed, a user terminal autonomously determines the changed reference signal pattern, and thus, it is possible to eliminate a need of signaling for notifying such a change. Therefore, it is possible to change the density of the reference signal without increasing the signaling.

[0043] In the embodiment, the reference signal is a downlink reference signal commonly applied to a plurality of user terminals that communicate with the base station.

[0044] In the embodiment, the control unit determines a reference signal pattern having a highest correlation value with the received radio signal, out of the plurality of reference signal patterns, as a reference signal pattern applied to the received radio signal.

[0045] In the embodiment, the control unit determines the reference signal pattern only when a difference between the correlation values calculated for each of the plurality of reference signal patterns is greater than a threshold value.

[0046] In the embodiment, when the base station changes the reference signal pattern at a predetermined timing, the control unit determines the reference signal pattern in accordance with the predetermined timing.

[0047] In the embodiment, the plurality of reference signal patterns include: a first reference signal pattern having a predetermined reference signal density in a frequency-axis direction; and a second reference signal pattern having a reference signal density lower than the predetermined reference signal density in a frequency-axis direction.

[0048] In the embodiment, the first reference signal pattern is a pattern in which the reference signals are arranged in all resource blocks in the frequency-axis direction, and the second reference signal pattern is a pattern in which the reference signals are arranged in only some resource blocks in the frequency-axis direction.

[0049] In the embodiment, the plurality of reference signal patterns include: a first reference signal pattern having a predetermined reference signal density in a time-axis direction; and a second reference signal pattern having a reference signal density lower than the predetermined reference signal density in the time-axis direction.

[0050] In the embodiment, the first reference signal pattern is a pattern in which the reference signals are arranged evenly in all subframes in a time-axis direction, and the second reference signal pattern is a pattern in which the reference signals are arranged evenly in some subframes in the time-axis direction, and the reference signals are partially arranged in the remaining subframes.

[0051] In the embodiment, the control unit increases, when it is possible to determine that there is a small variation in the channel characteristic, a priority of a reference signal pattern determined last time, and determines the reference signal pattern this time.

[0052] A processor according to the embodiment is provided in a user terminal that communicates with a base station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The processor performs: a process for storing a plurality of reference signal patterns each having a different density of the reference signal; a process for receiving the radio signal including the reference signal, from the base station; and a process for determining a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

[0053] A communication control method according to the embodiment is used for a user terminal that communicates with a base station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received. The communication control method comprises: a step A of storing a plurality of reference signal patterns each having a different density of the reference signal; a step B of receiving the radio signal including the reference signal, from the base station; and a step C of determining a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

Embodiment

[0054] Hereinafter, with reference to the accompanying drawings, a description will be provided for an embodiment when the present invention is applied to a mobile communication system (an LTE system) configured in accordance with 3GPP standards.

[0055] (LTE System)

[0056] FIG. **1** is a configuration diagram of the LTE system according to the present embodiment.

[0057] As illustrated in FIG. **1**, the LTE system includes a plurality of UEs (User Equipments) **100**, E-UTRAN (Evolved Universal Terrestrial Radio Access Network) **10**, and EPC (Evolved Packet Core) **20**. The EPC **20** corresponds to a core network.

[0058] The UE **100** is a mobile radio communication device and performs radio communication with a cell (a serving cell) with which a connection is established. The UE **100** corresponds to the user terminal.

[0059] The E-UTRAN **10** includes a plurality of eNBs **200** (evolved Node-Bs). The eNB **200** corresponds to a base station. The eNB **200** configures a cell or a plurality of cells and performs radio communication with the UE **100** that establishes a connection with the cell.

[0060] It is noted that the "cell" is used as a term indicating a minimum unit of a radio communication area, and is also used as a term indicating a function of performing radio communication with the UE **100**.

[0061] The eNB **200**, for example, has a radio resource management (RRM) function, a routing function of user data, and a measurement control function for mobility control and scheduling.

[0062] The EPC **20** includes a plurality of MME (Mobility Management Entity)/S-GWs (Serving-Gateways) **300**.

[0063] The MME is a network node for performing various mobility controls, for example, for the UE **100** and corresponds to a controller. The S-GW is a network node that performs transfer control of user data and corresponds to a mobile switching center. The EPC **20** including the MME/S-GW **300** accommodates the eNB **200**.

[0064] The eNBs **200** are connected mutually via an X2 interface. Furthermore, the eNB **200** is connected to the MME/S-GW **300** via an S1 interface.

[0065] Next, the configurations of the UE **100** and the eNB **200** will be described.

[0066] FIG. **2** is a block diagram of the UE **100**. As illustrated in FIG. **2**, the UE **100** includes an antenna **101**, a radio transceiver **110**, a user interface **120**, a GNSS (Global Navigation Satellite System) receiver **130**, a battery **140**, a memory **150**, and a processor **160**. The memory **150** and the processor **160** constitute a control unit.

[0067] The UE **100** may not have the GNSS receiver **130**. Furthermore, the memory **150** may be integrally formed with the processor **160**, and this set (that is, a chipset) may be called a processor **160'**.

[0068] The antenna **101** and the radio transceiver **110** are used to transmit and receive a radio signal. The antenna **101** includes a plurality of antenna elements. The radio transceiver **110** converts a baseband signal output from the processor **160** into the radio signal, and transmits the radio signal from the antenna **101**. Furthermore, the radio transceiver **110** converts the radio signal received by the antenna **101** into the baseband signal, and outputs the baseband signal to the processor **160**.

[0069] The user interface **120** is an interface with a user carrying the UE **100**, and includes, for example, a display, a microphone, a speaker, and various buttons. The user interface **120** receives an operation from a user and outputs a signal indicating the content of the operation to the processor **160**.

[0070] The GNSS receiver **130** receives a GNSS signal in order to obtain location information indicating a geographical location of the UE **100**, and outputs the received signal to the processor **160**.

[0071] The battery **140** accumulates a power to be supplied to each block of the UE **100**.

[0072] The memory **150** stores a program to be executed by the processor **160** and information to be used for a process by the processor **160**.

[0073] The processor **160** includes a baseband processor that performs modulation and demodulation, encoding and decoding and the like of the baseband signal, and a CPU (Central Processing Unit) that performs various processes by executing the program stored in the memory **150**. The processor **160** may further include a codec that performs coding and decoding of sound and video signals. The processor **160** implements various processes and various communication protocols described later.

[0074] FIG. **3** is a block diagram of the eNB **200**. As illustrated in FIG. **3**, the eNB **200** includes an antenna **201**, a radio transceiver **210**, a network interface **220**, a memory **230**, and a processor **240**. The memory **230** and the processor **240** constitute a control unit. It is noted that the memory **230** may be integrally formed with the processor **240**, and this set (that is, a chipset) may be called a processor.

[0075] The antenna **201** and the radio transceiver **210** are used to transmit and receive a radio signal. The antenna **201** includes a plurality of antenna elements. The radio trans-

ceiver **210** converts the baseband signal output from the processor **240** into the radio signal, and transmits the radio signal from the antenna **201**. Furthermore, the radio transceiver **210** converts the radio signal received by the antenna **201** into the baseband signal, and outputs the baseband signal to the processor **240**.

[0076] The network interface **220** is connected to the neighboring eNB **200** via the X2 interface and is connected to the MME/S-GW **300** via the S1 interface. The network interface **220** is used in communication performed on the X2 interface and communication performed on the S1 interface.

[0077] The memory **230** stores a program to be executed by the processor **240** and information to be used for a process by the processor **240**.

[0078] The processor **240** includes the baseband processor that performs modulation and demodulation, encoding and decoding and the like of the baseband signal and a CPU that performs various processes by executing the program stored in the memory **230**. The processor **240** implements various processes and various communication protocols described later.

[0079] FIG. **4** is a protocol stack diagram of a radio interface in the LTE system.

[0080] As illustrated in FIG. **4**, the radio interface protocol is classified into a layer 1 to a layer 3 of an OSI reference model, wherein the layer 1 is a physical (PHY) layer. The layer 2 includes a MAC (Media Access Control) layer, an RLC (Radio Link Control) layer, and a PDCP (Packet Data Convergence Protocol) layer. The layer 3 includes an RRC (Radio Resource Control) layer.

[0081] The PHY layer performs encoding and decoding, modulation and demodulation, antenna mapping and demapping, and resource mapping and demapping. Between the PHY layer of the UE **100** and the PHY layer of the eNB **200**, data is transmitted via the physical channel.

[0082] The MAC layer performs preferential control of data, and a retransmission process and the like by hybrid ARQ (an HARQ). Between the MAC layer of the UE **100** and the MAC layer of the eNB **200**, data is transmitted via a transport channel. The MAC layer of the eNB **200** includes a scheduler that determines an uplink and downlink transport format (a transport block size, a modulation and coding scheme and the like) and an assignment resource block.

[0083] The RLC layer transmits data to an RLC layer of a reception side by using the functions of the MAC layer and the PHY layer. Between the RLC layer of the UE **100** and the RLC layer of the eNB **200**, data is transmitted via a logical channel.

[0084] The PDCP layer performs header compression and decompression, and encryption and decryption.

[0085] The RRC layer is defined only in a control plane. Between the RRC layer of the UE **100** and the RRC layer of the eNB **200**, a control message (an RRC message) for various types of setting is transmitted. The RRC layer controls the logical channel, the transport channel, and the physical channel in response to establishment, re-establishment, and release of a radio bearer. When an RRC connection is established between the RRC of the UE **100** and the RRC of the eNB **200**, the UE **100** is in a connection state (RRC connected state), and when the RRC connection is not established, the UE **100** is in an idle state (RRC idle state).

[0086] A NAS (Non-Access Stratum) layer positioned above the RRC layer performs session management or mobility management, for example.

[0087] FIG. **5** is a configuration diagram of a radio frame used in the LTE system. In the LTE system, OFDMA (Orthogonal Frequency Division Multiplexing Access) is applied to a downlink, and SC-FDMA (Single Carrier Frequency Division Multiple Access) is applied to an uplink, respectively.

[0088] As illustrated in FIG. **5**, the radio frame is configured by 10 subframes arranged in a time direction, wherein each subframe is configured by two slots arranged in the time direction. Each subframe has a length of 1 ms and each slot has a length of 0.5 ms. Each subframe includes a plurality of resource blocks (RBs) in a frequency direction, and a plurality of symbols in the time direction. Each symbol is provided at ahead thereof with a guard interval called a cyclic prefix (CP). The resource block includes a plurality of subcarriers in the frequency direction. A minimum resource unit configured by one subcarrier and one symbol is called a resource element (RE).

[0089] Also, Among radio resources assigned to the UE **100**, a frequency resource can be designated by a resource block and a time resource can be designated by a subframe (or slot).

[0090] In the downlink, an interval of several symbols at the head of each subframe is a control region mainly used as a physical downlink control channel (PDCCH). Furthermore, the other interval of each subframe is a region mainly used as a physical downlink shared channel (PDSCH).

[0091] In a downlink, downlink reference signals such as a cell-specific reference signal (CRS) and/or a channel-state-information reference signal (CSI-RS) are dispersed and arranged in each subframe. The downlink reference signal is configured by a predetermined orthogonal signal sequence, and arranged in a predetermined resource element.

[0092] In the uplink, both end portions in the frequency direction of each subframe are control regions mainly used as a physical uplink control channel (PUCCH). Furthermore, the center portion, in the frequency direction, of each subframe is a region mainly used as a physical uplink shared channel (PUSCH).

[0093] (Operation According to Embodiment)

[0094] Hereinafter, an operation according to the present embodiment will be described.

[0095] (1) Operation Overview

[0096] FIG. **6** is a diagram showing an operation environment according to the present embodiment. In the present embodiment, a downlink is mainly described.

[0097] As shown in FIG. **6**, UE **100-1** to UE **100-*n*** each establish a connection with the eNB **200**, and communicate with the eNB **200**.

[0098] In the present embodiment, a case where the eNB **200** uses one carrier in the downlink is assumed. However, the eNB **200** may use a plurality of carriers in the downlink. The plurality of carriers may include a primary carrier (primary cell) and a secondary carrier (secondary cell).

[0099] The eNB **200** transmits a radio signal including CRS and/or CSI-RS in the downlink. The CRSs and/or CSI-RSs are arranged over the entire carrier band. The CRS and/or CSI-RS are a downlink common reference signal applied in common to a plurality of UEs **100**. The CRS and/or CSI-RS are referred to as a "downlink reference signal", below.

[0100] It is noted that in addition to transmitting the CRS and/or CSI-RS, the eNB **200** transmits DMRS that is a demodulation reference signal of a downlink, applied individually to the UE **100**.

[0101] On the basis of the downlink reference signal included in the radio signal received from the eNB **200**, the UE **100** estimates a channel characteristic between the UE **100** and the eNB **200** (channel estimation), and feeds back channel state information (CSI) to the eNB **200** on the basis of a result of the channel estimation.

[0102] It is noted that the channel estimation is a process in which a channel estimation value in RE unit is subject to an averaging process or a filter process in a frequency-axis direction or a time-axis direction so as to evaluate a channel characteristic in which influence such as noise is minimized.

[0103] CSI is at least one of: channel quality information (CQI; Channel Quality Indicator), precoder matrix information (PMI; Precoder Matrix Indicator), and rank information (RI; Rank Indicator). CQI is an index showing a modulation and coding scheme (MCS) recommended in a downlink. PMI is an index showing a precoder matrix recommended in a downlink. RI is an index showing a rank recommended in a downlink.

[0104] The eNB **200** controls a downlink communication with the UE **100** on the basis of the CSI fed back from the UE **100**. For example, the eNB **200** performs scheduling for the UE **100** on the basis of the CQI. Further, the eNB **200** controls a multi-antenna transmission for the UE **100** on the basis of the PMI and the RI.

[0105] In the present embodiment, the eNB **200** dynamically changes a density of a downlink reference signal applied to communication among the UE **100-1** to the UE **100-*n*** (hereinafter, "reference signal density"). Specifically, the eNB **200** calculates a statistics amount of communication quality information acquired for all the UE **100-1** to the UE **100-*n***, and changes the reference signal density on the basis of the statistics amount.

[0106] The communication quality information is at least one of: throughput for each UE **100**, CQI for each UE **100**, a moving speed for each UE **100**, or a delay dispersion range for each UE **100**, for example. Further, examples of the statistics amount include an average of communication quality information, a worst value of communication quality information, or a cumulative distribution function (CDF) of communication quality information.

[0107] For example, when the eNB **200** uses a predetermined reference signal density for the communication with the UE **100-1** to the UE **100-*n***, the eNB **200** changes the reference signal density to a reference signal density lower than the predetermined reference signal density in accordance with improvement on the statistics amount.

[0108] Further, when the eNB **200** uses a predetermined reference signal density for the communication with the UE **100-1** to the UE **100-*n***, the eNB **200** changes the reference signal density to a reference signal density higher than the predetermined reference signal density in accordance with deterioration of the statistics amount.

[0109] The eNB **200** changes the reference signal density by changing an arrangement pattern of the downlink reference signal in a radio signal (hereinafter, "reference signal pattern").

[0110] The UE **100** previously stores a plurality of reference signal patterns in which the reference signal density differs. The UE **100** determines the reference signal pattern applied to the received radio signal on the basis of a correlation value between the radio signal received from the eNB **200** and each of the plurality of reference signal patterns.

[0111] Specifically, the UE **100** determines, as the reference signal pattern applied to the received radio signal, a reference signal pattern having the highest correlation value with the received radio signal out of the plurality of reference signal patterns. Then, the UE **100** performs the above-described channel estimation on the basis of the determined reference signal pattern.

[0112] (2) Reference Signal Pattern

[0113] Next, the reference signal pattern according to the present embodiment will be described. The reference signal pattern regarding the CRS will be mainly described below.

[0114] In the present embodiment, as the reference signal pattern, two reference signal patterns, that is, a first reference signal pattern having a predetermined reference signal density (hereinafter, "reference signal pattern A"), and a second reference signal pattern having a reference signal density lower than the predetermined reference signal density (hereinafter, "reference signal pattern B"), are used. However, the number of the reference signal patterns is not limited to two, and may be three or more.

[0115] FIG. **7** is a frame configuration diagram for explaining the reference signal pattern A according to the present embodiment.

[0116] As shown in FIG. **7**, in the reference signal pattern A, the downlink reference signals are dispersed and arranged in a time-axis direction and a frequency-axis direction. Specifically, in the time-axis direction, the downlink reference signals are arranged in all the subframes. Further, in the frequency-axis direction, the downlink reference signals are arranged in all the resource blocks (RBs).

[0117] FIG. **8** is a diagram showing an arrangement example of the downlink reference signals in one subframe and one RB.

[0118] As shown in FIG. **8**, four REs are secured as a reference signal-use resource in each of first-half slots and second-half slots in one subframe (subframe N), and thus, a total of eight REs are secured as the reference signal-use resource.

[0119] Next, the reference signal pattern B will be described while focusing on a difference from the reference signal pattern A.

[0120] FIG. **9** is a frame configuration diagram for explaining a specific example 1 of the reference signal pattern B.

[0121] As shown in FIG. **9**, in the specific example 1 of the reference signal pattern B, the downlink reference signals are not arranged in all the subframes in the time-axis direction, and are arranged only in either one of the consecutive two subframes. Further, the downlink reference signals are not arranged in all the RBs in the frequency-axis direction, and are arranged only in either one of the consecutive two RBs.

[0122] FIG. **10** is a frame configuration diagram for explaining a specific example 2 of the reference signal pattern B.

[0123] As shown in FIG. **10**, the specific example 2 of the reference signal pattern B differs from the above-described specific example 1 in that a downlink reference signal in a control region (PDCCH region) is left. As a result, it becomes possible to use the downlink reference signal for decoding PDCCH.

[0124] FIG. **11** is a frame configuration diagram for explaining a specific example 3 of the reference signal pattern B.

[0125] As shown in FIG. **11**, the specific example 3 of the reference signal pattern B differs from the above-described

specific example 1 in that the downlink reference signal in the control region is left and a downlink reference signal in a head portion (or a first-half portion) in a data region (PDSCH region) is left. As a result, it becomes possible to use the downlink reference signal for decoding PDSCH.

[0126] Thus, the specific examples 2 and 3 of the reference signal pattern B is a pattern in which, in the time-axis direction, the downlink reference signals are arranged evenly in some of the subframes and the downlink reference signals are arranged partially in the remaining subframe.

[0127] It is noted that a position of the RE used as the reference signal resource may be the same between the reference signal patterns A and B, and the position of the RE used as the reference signal resource may differ between the reference signal patterns A and B.

[0128] (3) Operation Sequence

[0129] Next, an operation sequence according to the present embodiment will be described. FIG. **12** is an operation sequence diagram according to the present embodiment.

[0130] As shown in FIG. **12**, in step S**10**, the eNB **200** transmits the radio signal including the downlink reference signal. The UE **100-1** to the UE **100-***n* each receive the radio signal including the downlink reference signal.

[0131] In step S**20**, the UE **100-1** to the UE **100-***n* each determine the reference signal pattern applied to the radio signal received in step S**10**. A process for determining the reference signal pattern will be described in detail later.

[0132] In step S**30**, the UE **100-1** to the UE **100-***n* each perform a measurement process including the channel estimation on the basis of the downlink reference signal having the reference signal pattern determined instep S**20**. Further, the UE **100-1** to the UE **100-***n* each perform a reception process for user data on the basis of a result of the channel estimation.

[0133] In step S**40**, the UE **100-1** to the UE **100-***n* each transmit the communication quality information to the eNB **200**. The communication quality information transmitted in this step is information indicating communication quality measured by the UE **100**, and is throughput or CQI, for example. The throughput preferably is throughput for each predetermined time width rather than instantaneous throughput. It is noted that the moving speed measured in the UE **100** itself may be the communication quality information. The eNB **200** receives the communication quality information.

[0134] In step S**50**, the eNB **200** performs measurement process for an uplink, on each of the UE **100-1** to the UE **100-***n*. For example, the eNB **200** measures the delay dispersion range for each UE **100**, as the communication quality information. It is noted that the eNB **200** may measure a phasing frequency for each UE **100**, and acquire a moving speed estimated from the phasing frequency, as the communication quality information.

[0135] It is noted that both or only either one of steps S**40** and S**50** may be executed.

[0136] In step S**60**, the eNB **200** determines whether to change the reference signal pattern. Specifically, the eNB **200** calculates the statistics amount of the communication quality information acquired for all the UE **100-1** to the UE **100-***n*, and makes the determination on the basis of the statistics amount. A process for changing the reference signal pattern will be described in detail later.

[0137] In this case, description is provided on assumption that it is determined that the reference signal pattern is changed.

[0138] In step S**70**, the eNB **200** transmits the radio signal including the downlink reference signal by applying the changed reference signal pattern. The UE **100-1** to the UE **100-***n* each receive the radio signal including the downlink reference signal. Thereafter, processes after step S**20** are performed again.

[0139] It is noted that a cycle in which the eNB **200** determines to change the reference signal pattern may be one subframe or two subframes. This cycle is shared with the UE **100**, and the UE **100** determines the reference signal pattern at a timing corresponding to the cycle in which the eNB **200** determines to change the reference signal pattern. As a result, it is possible to avoid wasted correlation calculation being performed in the UE **100**.

[0140] (4) Operation of UE **100**

[0141] Next, an operation of the UE **100** according to the present embodiment will be described. FIG. **13** is an operation flowchart showing a reference-signal-pattern determination process by the UE **100**, that is, a details of step S**20** in FIG. **12**.

[0142] As a precondition for the present operation flow, the memory **150** previously stores the reference signal patterns A and B as a reference signal. Further, when the eNB **200** changes the reference signal pattern at a predetermined timing, the processor **160** executes the present operation flow in tune with the predetermined timing.

[0143] As shown in FIG. **13**, in step S**21**, the processor **160** calculates correlation values A and B between a radio signal received from the eNB **200** by the radio transceiver **110** (hereinafter, "received signal") and each of the reference signal patterns A and B.

[0144] In this case, the received signal for correlation preferably is a signal obtained after the channel estimation and the channel equalization thereof on the assumption of sequences of the reference signal patterns A and B rather than a raw received value. It is noted that the channel estimation is a process in which a channel estimation value in RE unit is subject to an averaging process or a filter process in a frequency-axis direction or a time-axis direction so as to evaluate a channel characteristic in which influence such as noise is minimized. The channel equalization is a process in which an inverse characteristic of the channel characteristic evaluated above is multiplied so as to restore the influence of the channel.

[0145] The correlation value A can be calculated according to the below Equation (1), where "Ai" denotes a reference signal corresponding to the reference signal pattern A and "Rxi" denotes the received signal.

[Equation 1]

$$\text{Correlation value } A = \mathrm{Re}\left[\frac{1}{N}\sum_{i=1}^{N} A_i Rx_i^*\right] \quad (1)$$

[0146] where "i" denotes an index of a reference RE and "N" denotes an RE number used for a correlation process. Further, the above Equation is such that Ai and Rxi are both set when power (amplitude) of a signal is assumed to be normalized to 1. It is noted that the RE for correlation may be freely bundled in the time-axis direction or in the frequency-axis direction. Alternately, when determination is made in a unit of subframe, all REs in a subframe may be one group.

[0147] The correlation value B can be calculated according to the below Equation (2) obtained by modifying the above Equation (1), where "Bi" denotes a reference signal corresponding to the reference signal pattern B.

[Equation 2]

$$\text{Correlation value } B = \mathrm{Re}\left[\frac{1}{N}\sum_{i=1}^{N} B_i R x_i^*\right] \quad (2)$$

[0148] In step S**22**, the processor **160** compares the correlation values A and B calculated in step S**21**, and determines a reference signal pattern corresponding to a higher correlation value, as a reference signal pattern applied to the received signal. When the reference signal pattern is determined in this manner, the processor **160** performs a channel estimation, etc., on the basis of the determined reference signal pattern, in a reception process of PDCCH, PDSCH, etc.

[0149] It is noted that only when a difference between the correlation values A and B (absolute value of a difference |A−B|) is greater than a threshold value, the reference signal pattern may be determined. That is, when the difference between the correlation values A and B is equal to or less than the threshold value, the processor **160** continues to apply the reference signal pattern determined last time without determining the reference signal pattern, and waits for determining a reference signal pattern next.

[0150] Further, when it is possible to determine that a variation of the channel characteristic is small, the processor **160** may raise the priority of the reference signal pattern determined last time, and then, may determine the reference signal pattern this time. This is because when there is a small variation in the channel characteristic, it is highly probable that the reference signal pattern determined last time is maintained.

[0151] FIG. **14** and FIG. **15** are diagrams for explaining a specific example of a reference signal pattern determination. In this case, one example is described in which when the reference signal pattern applied to the received signal is the reference signal pattern A, the processor **160** determines the reference signal pattern.

[0152] As shown in FIG. **14**, the processor **160** calculates a correlation value A between the received signal Rxi and the reference signal Ai corresponding to the reference signal pattern A, in accordance with the above Equation (1).

[0153] As shown in FIG. **15**, the processor **160** calculates a correlation value B between the received signal Rxi and the reference signal Bi corresponding to the reference signal pattern B, in accordance with the above Equation (2)

[0154] In this example, the reference signal pattern applied to the received signal is the reference signal pattern A, and thus, the correlation value A becomes higher than the correlation value B. Therefore, the processor **160** determines that the reference signal pattern applied to the received signal is the reference signal pattern A.

[0155] (5) Operation of eNB **200**

[0156] Next, an operation of the eNB **200** according to the present embodiment will be described. FIG. **16** is an operation flowchart showing a reference-signal-pattern change process by the eNB **200**, that is, a detail of step S**60** in FIG. **12**.

[0157] As shown in FIG. **16**, in step S**61**, the processor **240** calculates a statistics amount of the communication quality information acquired for all the UE **100-1** to the UE **100-*n***. The communication quality information is at least one of: throughput for each UE **100**, CQI for each UE **100**, a moving speed for each UE **100**, or a delay dispersion range for each UE **100**, for example. Further, examples of the statistics amount include an average of communication quality information, a worst value of communication quality information, or CDF of communication quality information.

[0158] In this case, the processor **240** may exclude UE **100**, in which the degree of a variation of the corresponding communication quality information is greater than a threshold value, out of the UE **100-1** to the UE **100-*n***, from a target of calculating the statistics amount. As a result, it becomes possible to appropriately calculate the statistics amount. For example, the statistics amount is calculated while only UE **100** having a small time dispersion such as throughput is subject to calculation.

[0159] Further, the processor **240** excludes, UE **100** in which a data amount corresponding to an application to be executed is less than a threshold value, out of the UE **100-1** to the UE **100-*n***, from a target of calculating the statistics amount. This is because it is not necessary to improve the throughput in the UE **100** to and from which a small amount of data is transmitted and received.

[0160] In step S**62**, the processor **240** compares the statistics amount calculated instep S**61** with a threshold value.

[0161] In step S**63**, the processor **240** determines whether to change the reference signal pattern in response to a comparison result in step S**62**.

[0162] When it is determined that the reference signal pattern is changed (step S**63**; YES), the processor **240** changes the reference signal pattern in step S**64**.

[0163] Next, a specific example in which it is determined to change the reference signal pattern will be described.

[0164] Firstly, a specific example in which the communication quality information is throughput for each UE **100** will be described. When the communication quality information is throughput for each UE **100**, the statistics amount can be average throughput or CDF.

[0165] FIG. **17** is a diagram showing one example of the average throughput as the statistics amount.

[0166] As shown in FIG. **17**, the average throughput changes along with passage of time. The processor **240** compares the average throughput at current time point t with a threshold value. The threshold value can be set according to the below Equation (3).

[Equation 3]

$$\text{Threshold value} = \frac{\text{theoretical Max Throughput}}{\text{the number of connection UE}} \quad (3)$$

[0167] When the average throughput is smaller than the threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve a communication environment (improve channel estimation accuracy).

[0168] In contrast, when the average throughput is greater than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0169] It is noted that the average throughput may be the average throughput at current time point t and may also be a value obtained by weighting and averaging a past value and a

current value. The processor **240** calculates a weighted average so that the weight of the current value is larger.

[0170] FIG. **18** is a diagram showing one example of the throughput CDF as the statistics amount.

[0171] As shown in FIG. **18**, throughputs are arranged in ascending order and then a cumulative distribution is obtained. FIG. **18** shows CDF at a time a and CDF at a time b.

[0172] When the number of the UEs **100** that stay in the bottom 5% of throughput is less than a threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve the communication environment (improve the channel estimation accuracy).

[0173] In contrast, when the number of the UEs **100** that stay in the bottom 5% of throughput is equal to or more than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0174] Therefore, the reference signal pattern A is applied to the time a, and the reference signal pattern B is applied to the time b.

[0175] FIG. **19** is a diagram showing one example of throughput CDF, as the statistics amount.

[0176] As shown in FIG. **19**, the processor **240** calculates a gradient between 5% and 95% in CDF (=Δy/Δx), and compares the calculated gradient with a previously set threshold value of a gradient. It is possible to understand that the greater the gradient between 5% and 95% in CDF, the more stable the communication environment of all the UEs **100**.

[0177] When the calculated gradient is smaller than the threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve the communication environment (improve the channel estimation accuracy).

[0178] In contrast, when the calculated gradient is greater than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0179] Secondly, a specific example in which the communication quality information is CQI for each UE **100** will be described. When the communication quality information is CQI for each UE **100**, the statistics amount may be an average CQI. The CQI is indicated in numerical value from 0 to 15, for example, and the greater the value, the better the communication environment.

[0180] When the average CQI is smaller than a threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve the communication environment (improve the channel estimation accuracy).

[0181] In contrast, when the average CQI is greater than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0182] Thirdly, a specific example in which the communication quality information is the moving speed for each UE **100** will be described. When the communication quality information is the moving speed for each UE **100**, the statistics amount may be an average moving speed. It is possible to understand that the lower the moving speed, the more stable the communication environment.

[0183] When the average moving speed is greater than a threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve the communication environment (improve the channel estimation accuracy).

[0184] In contrast, when the average moving speed is smaller than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0185] It is noted that when the communication quality information is the moving speed for each UE **100**, it is possible to appropriately adjust the channel estimation accuracy by changing the reference signal density in the time-axis direction rather than by changing the reference signal density in the frequency-axis direction.

[0186] Fourthly, a specific example in which when the communication quality information is the throughput, the CQI, or the moving speed for each UE **100**, and the statistics amount is a worst value will be described. In this case, the worst value of the moving speed is a highest moving speed. When the statistics amount is the worst value, it is possible to apply a determination method similar to that for the above-described average value.

[0187] Fifthly, a specific example in which the communication quality information is the delay dispersion range and the statistics amount is the worst value will be described.

[0188] The delay dispersion range is a time range between a preceding wave and a delayed wave. Specifically, it is possible to regard a range from a mountain having largest power to a mountain having from the power to power within a predetermined range as the delay dispersion range. Alternately, it may be also possible to regard a range having a mountain having power equal to or more than a predetermined level as the delay dispersion range.

[0189] Further, the worst value of the delay dispersion range is the delay dispersion range in the UE **100** having a widest delay dispersion range.

[0190] FIG. **20** and FIG. **21** are diagrams showing one example of the worst value of the delay dispersion range, as the statistics amount.

[0191] As shown in FIG. **20**(*a*), when the delay dispersion range is wide, as shown in FIG. **20**(*b*), a variation in frequency characteristic is large, and thus, it is difficult to interpolate the channel estimation.

[0192] As shown in FIG. **21**(*a*), when the delay dispersion range is narrow, as shown in FIG. **21**(*b*), the variation in frequency characteristic is small, and thus, it is easy to interpolate the channel estimation.

[0193] Therefore, when the worst value of the delay dispersion range is greater than a threshold value, the processor **240** applies the reference signal pattern A having a high reference signal density in order to improve the communication environment (improve the channel estimation accuracy).

[0194] In contrast, when the worst value of the delay dispersion range is smaller than the threshold value, the processor **240** applies the reference signal pattern B having a low reference signal density in order to improve the throughput.

[0195] It is noted that when the communication quality information is the delay dispersion range, it is possible to appropriately adjust the channel estimation accuracy by changing the reference signal density in the frequency-axis direction rather than by changing the reference signal density in the time-axis direction.

[0196] (Conclusion of Embodiment)

[0197] In a mobile communication system in which a radio signal including a downlink reference signal for estimating a

channel characteristic is transmitted and received, the eNB **200** communicates with the UE **100-1** to the UE **100-*n***. The eNB **200** includes the processor **240** that changes a reference signal density that is a density of a downlink reference signal applied to the communication with the UE **100-1** to the UE **100-*n***. The processor **240** calculates a statistics amount of communication quality information acquired for all the UE **100-1** to the UE **100-*n***, and changes the reference signal density on the basis of the statistics amount.

[0198] As a result, it is possible to dynamically change the reference signal density while statistically determining a communication environment of all the UEs **100** connected with the eNB **200**, on the basis of a statistics amount of communication quality information.

[0199] In a mobile communication system in which a radio signal including a downlink reference signal for estimating a channel characteristic is transmitted and received, the UE **100** communicates with the eNB **200**. The UE **100** includes: the memory **150** that stores a plurality of reference signal patterns each having a different downlink reference signal density; the radio transceiver **110** that receives, from the eNB **200**, a radio signal including the downlink reference signal; and the processor **160** that determines the reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of a plurality of reference signal patterns.

[0200] Here, when the density of the reference signal is dynamically changed, there is a problem that signaling for notifying such a change increases.

[0201] According to the UE **100** of the present embodiment, even when the reference signal pattern (that is, the density of the downlink reference signal) is changed, the UE **100** autonomously determines the changed reference signal pattern, and thus, it is possible to eliminate a need of signaling for notifying such a change. Therefore, it is possible to change the density of the downlink reference signal without increasing the signaling.

Other Embodiments

[0202] Thus, the present invention has been described with the embodiments. However, it should not be understood that those descriptions and drawings constituting apart of this disclosure limit the present invention. From this disclosure, a variety of alternate embodiments, examples, and applicable techniques will become apparent to one skilled in the art.

[0203] In the above-described embodiment, a case where the reference signal density (reference signal pattern) in the downlink reference signal (downlink reference signal) is dynamically changed is mainly described. However, the present invention can be applied to a case where in addition to the downlink reference signal, a reference signal density in an uplink reference signal (specifically, DMRS) is dynamically changed.

[0204] In the above-described embodiment, a case where the eNB **200** uses one carrier in the downlink is mainly described. However, when the eNB **200** uses a plurality of carriers in the downlink, the eNB **200** may calculate a statistics amount for each carrier and may change the reference signal density for each carrier.

[0205] In the above-described embodiment, the category of the base station of the eNB **200** is not mentioned; however, the eNB **200** may be a small cell base station configuring a small cell (for example, a pico cell or a femto cell) smaller than a micro cell. In this case, the UE **100-1** to the UE **100-*n*** are connected with the small cell.

[0206] Generally, the number of UEs that can be housed in the small cell is smaller than that of UEs that can be housed in the micro cell. The eNB **200** calculates the statistics amount of the communication quality information acquired for all the UE **100-1** to the UE **100-*n***, and therefore, when a large number of UEs **100** are connected with the eNB **200**, the statistics amount is leveled. Therefore, when the eNB **200** is the small cell base station, the number of UEs **100** that is to be statistically processed is small, and therefore, it is possible to avoid such a problem.

[0207] The above-described embodiment has described an example in which the present invention is applied to an LTE system. However, the present invention may also be applied to systems, other than the LTE system, as well as the LTE system.

[0208] In addition, the entire content of U.S. Provisional Application No. 61/730,629 (filed on Nov. 28, 2012) and U.S. Provisional Application No. 61/730,635 (filed on Nov. 28, 2012) is incorporated in the present specification by reference.

INDUSTRIAL APPLICABILITY

[0209] As described above, a base station, a processor therefor, a communication control method therefor, and a user terminal according to the present invention, are possible to appropriately control the density of a reference signal, and thus are useful in a mobile communication field.

1. A base station that communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, the base station comprising:

a control unit that changes a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals, wherein

the control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

2. The base station according to claim **1**, wherein

the reference signal is a downlink reference signal commonly applied to the plurality of user terminals.

3. The base station according to claim **1**, wherein

the communication quality information is at least one of: throughput for each of the plurality of user terminals; CQI for each of the plurality of user terminals; a moving speed for each of the plurality of user terminals; and a delay dispersion range for each of the plurality of user terminals.

4. The base station according to claim **1**, wherein

the statistics amount is an average of the communication quality information, a worst value of the communication quality information, or a cumulative distribution function of the communication quality information.

5. The base station according to claim **1**, wherein

the control unit changes, when a predetermined reference signal density is used for the communication with the plurality of user terminals, the reference signal density to a reference signal density that is lower than the predetermined reference signal density, in accordance with improvement on the statistics amount.

6. The base station according to claim 1, wherein

the control unit changes, when a predetermined reference signal density is used for the communication with the plurality of user terminals, the reference signal density to a reference signal density that is higher than the predetermined reference signal density, in accordance with deterioration of the statistics amount.

7. The base station according to claim 1, wherein

the control unit excludes a user terminal, in which the degree of a variation of the corresponding communication quality information is greater than a threshold value, out of the plurality of user terminals, from a target for calculating the statistics amount.

8. The base station according to claim 1, wherein

the control unit excludes a user terminal, in which a data amount corresponding to an application to be executed is smaller than a threshold value, out of the plurality of user terminals, from a target of calculating the statistics amount.

9. The base station according to claim 1, wherein

the base station configures a small cell smaller than a macro cell, and

the plurality of user terminals are connected with the small cell.

10. A processor provided in a base station that communicates with a plurality of user terminals in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, wherein

the processor performs a process for calculating a statistics amount of communication quality information acquired for all the plurality of user terminals, and changing a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals on the basis of the statistics amount.

11. A communication control method used in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, the method comprising:

a step A of changing, by a base station that communicates with a plurality of user terminals, a reference signal density that is a density of the reference signal applied to communication with the plurality of user terminals, wherein

in the step A, the control unit calculates a statistics amount of communication quality information acquired for all the plurality of user terminals, and changes the reference signal density on the basis of the statistics amount.

12. A user terminal that communicates with a base station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, comprising:

a storage unit that stores a plurality of reference signal patterns each having a different density of the reference signal;

a reception unit that receives the radio signal including the reference signal, from the base station; and

a control unit that determines a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

13. The user terminal according to claim 12, wherein

the reference signal is a downlink reference signal commonly applied to a plurality of user terminals that communicate with the base station.

14. The user terminal according to claim 12, wherein

the control unit determines a reference signal pattern having a highest correlation value with the received radio signal, out of the plurality of reference signal patterns, as a reference signal pattern applied to the received radio signal.

15. The user terminal according to claim 12, wherein

the control unit determines the reference signal pattern only when a difference between the correlation values calculated for each of the plurality of reference signal patterns is greater than a threshold value.

16. The user terminal according to claim 12, wherein

when the base station changes the reference signal pattern at a predetermined timing, the control unit determines the reference signal pattern in accordance with the predetermined timing.

17. The user terminal according to claim 12, wherein

the plurality of reference signal patterns include:

a first reference signal pattern having a predetermined reference signal density in a frequency-axis direction; and

a second reference signal pattern having a reference signal density lower than the predetermined reference signal density in a frequency-axis direction.

18. The user terminal according to claim 17, wherein

the first reference signal pattern is a pattern in which the reference signals are arranged in all resource blocks in the frequency-axis direction, and

the second reference signal pattern is a pattern in which the reference signals are arranged in only some resource blocks in the frequency-axis direction.

19. The user terminal according to claim 12, wherein

the plurality of reference signal patterns include:

a first reference signal pattern having a predetermined reference signal density in a time-axis direction; and

a second reference signal pattern having a reference signal density lower than the predetermined reference signal density in the time-axis direction.

20. The user terminal according to claim 19, wherein

the first reference signal pattern is a pattern in which the reference signals are arranged evenly in all subframes in a time-axis direction, and

the second reference signal pattern is a pattern in which the reference signals are arranged evenly in some subframes in the time-axis direction, and the reference signals are partially arranged in the remaining subframes.

21. The user terminal according to claim 12, wherein

the control unit increases, when it is possible to determine that there is a small variation in the channel characteristic, a priority of a reference signal pattern determined last time, and determines the reference signal pattern this time.

22. A processor provided in a user terminal that communicates with a base station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, wherein the processor performs:

a process for storing a plurality of reference signal patterns each having a different density of the reference signal;

a process for receiving the radio signal including the reference signal, from the base station; and

a process for determining a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

23. A communication control method used for a user terminal that communicates with a base station in a mobile communication system in which a radio signal including a reference signal for estimating a channel characteristic is transmitted and received, the method comprising:

a step A of storing a plurality of reference signal patterns each having a different density of the reference signal;

a step B of receiving the radio signal including the reference signal, from the base station; and

a step C of determining a reference signal pattern applied to the received radio signal on the basis of a correlation value between the received radio signal and each of the plurality of reference signal patterns.

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