

DESCRIPTION

BASE STATION, COMMUNICATION TERMINAL,
TRANSMISSION METHOD, AND RECEPTION METHOD

5

TECHNICAL FIELD

The present invention generally relates to wireless communication technologies. More particularly, the present invention relates to a base station, a communication terminal, a transmission method, and a reception method used in a communication system where frequency scheduling and multicarrier transmission are employed.

15 BACKGROUND ART

In the field of wireless communication, there is a growing demand for a broadband wireless access system that enables efficient, high-speed, high-volume communications. For downlink channels in such a system, a multicarrier scheme such as orthogonal frequency division multiplexing (OFDM) appears to be a promising method to achieve high-speed, high-volume communications while effectively suppressing multipath fading. Also, in next generation systems, use of frequency scheduling is proposed to improve the frequency efficiency and thereby to increase the throughput.

As shown in FIG. 1, in next generation systems, a system frequency band is divided into multiple resource blocks (in this example, three resource blocks) each including one or more subcarriers. The resource blocks are also called frequency chunks. Each terminal is allocated one or more resource blocks. In a frequency scheduling method, to improve the transmission

efficiency or the throughput of the entire system, resource blocks are allocated preferentially to terminals with good channel conditions according to received signal quality or channel quality indicators (CQIs) measured and reported by the terminals based on downlink pilot channels for the respective resource blocks. When frequency scheduling is employed, it is necessary to report scheduling information indicating the results of scheduling to the terminals. The scheduling information is reported to the terminals via control channels (may also be called L1/L2 control signaling channels or associated control channels). The control channels are also used to report modulation schemes (e.g., QPSK, 16 QAM, or 64 QAM) and channel coding information (e.g., channel coding rates) used for scheduled resource blocks as well as information regarding hybrid automatic repeat request (HARQ). A method of dividing a frequency band into multiple resource blocks and using different modulation schemes for the respective resource blocks is, for example, disclosed in "A Practical Discrete Multitone Transceiver Loading Algorithm for Data Transmission over Spectrally Shaped Channel", P. Chow, J. Cioffi, J. Bingham, IEEE Trans. Commun. vol.43, No.2/3/4, February/March/April 1995.

DISCLOSURE OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

In a next generation wireless access system, various frequency bands, broad and narrow, may be employed and terminals may be required to use such various frequency bands depending on their locations or applications. For example, various reception frequency

bands may be provided for terminals with different applications or at different prices. Also in this case, appropriate frequency scheduling makes it possible to improve the frequency efficiency and the throughput.

5 However, because conventional communication systems are designed to use a fixed frequency band, no concrete method has been established yet for appropriately reporting scheduling information to terminals or users in a system where frequency bands with various

10 bandwidths are provided for the base station and the terminals and all combinations of the frequency bands are allowed.

When a resource block common to all terminals is statically allocated to a control channel, it may

15 happen that some terminals cannot receive the control channel with good quality because channel conditions of a resource block differ from terminal to terminal. Meanwhile, distributing a control channel to all resource blocks may make it possible for all terminals

20 to receive the control channel with certain reception quality. However, with this method, it is difficult to further improve the reception quality. For these reasons, there is a demand for a method of transmitting control channels with higher quality to terminals.

25 In a system where adaptive modulation and coding (AMC) is employed, i.e., where the modulation scheme and the channel coding rate used for a control channel are adaptively changed, the number of symbols used to transmit the control channel varies from

30 terminal to terminal. This is because the amount of information transmitted per symbol varies depending on the combination of the modulation scheme and the channel coding rate. For a next generation system, it is also

being discussed to send and receive different signals by multiple antennas provided at the sending and receiving ends. In this case, control information such as scheduling information as described above may be
5 necessary for each of the signals transmitted by the respective antennas. In other words, in such a system, the number of symbols necessary to transmit a control channel may differ from terminal to terminal and also differ depending on the number of antennas used by the
10 terminal. When the amount of information to be transmitted via a control channel varies from terminal to terminal, it is preferable to use a variable format that can flexibly accommodate various amounts of control information to improve resource use efficiency. However,
15 using a variable format may increase the signal processing workload at the sending and receiving ends. Meanwhile, when a fixed format is used, it is necessary to set the length of a control channel field to accommodate the maximum amount of control information.
20 In this case, even if a control channel occupies only a part of the control channel field, the resources for the remaining part of the control channel field cannot be used for data transmission and as a result, the resource use efficiency is reduced. For these reasons, there is a
25 demand for a method to transmit control channels in a simple and highly efficient manner.

Embodiments of the present invention make it possible to solve or reduce one or more problems caused by the limitations and disadvantages of the background
30 art. One object of the present invention is to provide a base station, a communication terminal, a transmission method, and a reception method that make it possible to efficiently transmit control channels to terminals

supporting different bandwidths in a communication system where each of multiple frequency blocks constituting a system frequency band includes multiple resource blocks each including one or more subcarriers
5 and each of the terminals communicates using one or more of the frequency blocks.

MEANS FOR SOLVING THE PROBLEMS

An aspect of the present invention provides a
10 base station used in a communication system where a system frequency band allocated to the communication system includes multiple frequency blocks and each of the frequency blocks includes multiple resource blocks each including one or more subcarriers. The base station
15 communicates with communication terminals each using one or more of the frequency blocks. The base station includes a management unit configured to manage the correspondence between bandwidths supported by the communication terminals and the frequency blocks to be
20 allocated to the communication terminals; a frequency scheduler configured to generate scheduling information for each of the frequency blocks to allocate one or more resource blocks to each of selected communication terminals having good channel conditions; a channel
25 generating unit configured to generate control channels including the scheduling information for the respective frequency blocks; a multiplexing unit configured to frequency-multiplex the control channels generated for the respective frequency blocks in the system frequency
30 band; and a transmitting unit configured to transmit an output signal from the multiplexing unit according to a multicarrier scheme.

Another aspect of the present invention

provides a base station including a coding and modulation unit configured to encode and modulate control channels including a general control channel to be decoded by communication terminals in general and
5 specific control channels to be decoded by selected communication terminals that are allocated one or more resource blocks; a multiplexing unit configured to time-division-multiplex the general control channel and the specific control channels according to scheduling
10 information; and a transmitting unit configured to transmit an output signal from the multiplexing unit according to a multicarrier scheme.

ADVANTAGEOUS EFFECT OF THE INVENTION

15 An aspect of the present invention makes it possible to efficiently transmit control channels to communication terminals supporting different bandwidths in a communication system where each of multiple frequency blocks constituting a system frequency band
20 includes multiple resource blocks each including one or more subcarriers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing used to describe frequency
25 scheduling;

FIG. 2 is a drawing illustrating a frequency band used in an embodiment of the present invention;

FIG. 3A is a partial block diagram (1) of a base station according to an embodiment of the present
30 invention;

FIG. 3B is a partial block diagram (2) of a base station according to an embodiment of the present invention;

FIG. 4A is a drawing illustrating signal processing components for one frequency block;

FIG. 4B is a drawing illustrating signal processing components for one frequency block;

5 FIG. 5A is a table showing exemplary information items of control signaling channels;

FIG. 5B is a drawing illustrating localized FDM and distributed FDM;

10 FIG. 6 is a drawing illustrating a unit of error correction coding;

FIG. 7A is a drawing illustrating exemplary mapping of data channels and control channels;

FIG. 7B is a drawing illustrating exemplary mapping of data channels and control channels;

15 FIG. 7C is a drawing illustrating exemplary multiplexing schemes for a general control channel;

FIG. 8A is a partial block diagram of a terminal according to an embodiment of the present invention;

20 FIG. 8B is a partial block diagram of a terminal according to an embodiment of the present invention;

FIG. 8C is a block diagram illustrating a receiving unit of a terminal;

25 FIG. 9A is a flowchart showing an exemplary process according to an embodiment of the present invention;

30 FIG. 9B is a drawing illustrating an exemplary method for reducing the amount of uplink data transmission information;

FIG. 10 is a drawing illustrating an example of frequency hopping;

FIG. 11 is a drawing illustrating an exemplary

process and a frequency band used in the process according to an embodiment of the present invention;

FIG. 12 is a drawing illustrating another exemplary process and a frequency band used in the process according to an embodiment of the present invention;

FIG. 13 is a drawing illustrating an example of transmission power control (TPC);

FIG. 14 is a drawing illustrating an example of adaptive modulation and coding (AMC);

FIG. 15 is a drawing illustrating allocation of radio resources for retransmission;

FIG. 16 is a drawing illustrating allocation of radio resources for retransmission;

FIG. 17 is a drawing illustrating allocation of radio resources for retransmission; and

FIG. 18 is a table showing a configuration of a grant for retransmission.

EXPLANATION OF REFERENCES

- 31 Frequency block allocation control unit
- 32 Frequency scheduling unit
- 33-x Control signaling channel generating unit for frequency block x
- 34-x Data channel generating unit for frequency block x
- 35 Broadcast channel (or paging channel) generating unit
- 1-x First multiplexing unit for frequency block x
- 37 Second multiplexing unit
- 38 Third multiplexing unit
- 39 Other channels generating unit
- 40 Inverse fast Fourier transform unit

- 41 Cyclic prefix adding unit
- 41 General control channel generating unit
- 42 Specific control channel generating unit
- 43 Multiplexing unit
- 5 81 Carrier frequency tuning unit
- 82 Filtering unit
- 83 Cyclic prefix removing unit
- 84 Fast Fourier transform unit (FFT)
- 85 CQI measuring unit
- 10 86 Broadcast channel decoding unit
- 87 General control channel decoding unit
- 88 Specific control channel decoding unit
- 89 Data channel decoding unit

15 BEST MODE FOR CARRYING OUT THE INVENTION

According to an embodiment of the present invention, frequency scheduling is performed for respective frequency blocks and control channels for reporting scheduling information using the minimum
20 bandwidth are generated for the respective frequency blocks. This method makes it possible to efficiently transmit control channels to communication terminals supporting various bandwidths.

The control channels generated for respective
25 frequency blocks may be frequency-division-multiplexed according to a predetermined hopping pattern. This method makes it possible to equalize the communication quality of multiple communication terminals and frequency blocks.

30 A broadcast channel may be transmitted using a frequency band including the center frequency of a system frequency band allocated to a communication system and having a bandwidth corresponding to one

frequency block. This method enables any communication terminal trying to access a communication system to easily connect to the communication system by receiving a signal transmitted using the minimum bandwidth around
5 the center frequency.

A paging channel may also be transmitted using a frequency band including the center frequency of a system frequency band allocated to a communication system and having a bandwidth corresponding to one
10 frequency block. This method enables a communication terminal to use the same frequency band for reception during the standby mode and for cell search, and is therefore preferable to reduce the number of times frequency tuning is performed.

Also, to equally use the entire frequency band,
15 a paging channel for paging a communication terminal may be transmitted using a frequency block allocated to the communication terminal.

According to an embodiment of the present
20 invention, control channels may include a general control channel to be decoded by communication terminals in general and specific control channels to be decoded by specific communication terminals that are allocated one or more resource blocks, and the general control
25 channel and the specific control channels may be encoded and modulated separately. The general control channel and the specific control channels are time-division-multiplexed according to scheduling information and transmitted using a multicarrier scheme. This method
30 makes it possible to efficiently transmit control channels using a fixed format without wasting resources even when the amount of control information varies from communication terminal to communication terminal.

The general control channel may be mapped so as to be distributed across the entire system frequency band and the specific control channels for specific communication terminals may be mapped only to resource
5 blocks allocated to the specific communication terminals. That is, the specific control channels are mapped to resource blocks that provide good channel conditions for the respective specific communication terminals. Accordingly, this method makes it possible to improve
10 the quality of the specific control channels while maintaining the quality of the general control channel at above a certain level for all users.

A downlink pilot channel may also be mapped so as to be distributed across multiple resource blocks
15 allocated to multiple communication terminals. Mapping a pilot channel across a wide band, for example, makes it possible to improve the accuracy of channel estimation.

According to an embodiment of the present invention, to maintain or improve the reception quality
20 of control channels including a general control channel and specific control channels, transmission power control is performed for the general control channel and one or both of transmission power control and adaptive modulation and coding are performed for the specific
25 control channels.

Transmission power control may be performed for the general control channel such that the reception quality of the general control channel at specific communication terminals that are allocated resource
30 blocks is improved. That is, although all users or communication terminals receiving a general control channel try to demodulate the general control channel, it is enough if users who are allocated resource blocks

can successfully demodulate the general control channel.

The general control channel may include information on modulation schemes and/or coding schemes applied to the specific control channels. Since the
5 combination of a modulation scheme and a coding scheme for the general control channel is fixed, users who are allocated resource blocks can obtain information on the modulation schemes and the coding schemes used for the specific control channels by demodulating the general
10 control channel. In other words, this method makes it possible to perform adaptive modulation and coding for the specific control channels and thereby to improve the reception quality of the specific control channels.

When both transmission power control and
15 adaptive modulation and coding are performed for the specific control channels, the total number of combinations of modulation schemes and coding schemes for the specific control channels may be less than the total number of combinations of modulation schemes and
20 coding schemes for a shared data channel. This is because even if the required quality of the specific control channels is not achieved solely by adaptive modulation and coding, there is no problem as long as the required quality can be achieved by additionally
25 performing transmission power control.

<FIRST EMBODIMENT>

FIG. 2 is a drawing illustrating a frequency band used in an embodiment of the present invention.
30 Values used in the descriptions below are just examples and different values may be used. In the example shown in FIG. 2, a frequency band (entire transmission band) allocated to a communication system has a bandwidth of

20 MHz. The entire transmission band includes four frequency blocks 1 through 4. Each of the frequency blocks includes multiple resource blocks each including one or more subcarriers. FIG. 2 schematically shows
5 frequency blocks each including multiple subcarriers. In this embodiment, four different communication bandwidths of 5 MHz, 10 MHz, 15 MHz, and 20 MHz are provided. A communication terminal performs communications using one or more frequency blocks corresponding to one of the
10 four bandwidths. A communication terminal in the communication system may support all of the four bandwidths or support only a part of the four bandwidths. Still, each communication terminal at least supports the 5 MHz bandwidth.

15 In this embodiment, control channels (L1/L2 control signaling channels or lower-layer control channels) for reporting scheduling information of data channels (shared data channels) to terminals are formed using the minimum bandwidth (5 MHz) and are provided for
20 each frequency block. For example, when a terminal supporting the 5 MHz bandwidth performs communications using frequency block 1, the terminal receives control channels provided for frequency block 1 and thereby obtains scheduling information. Information indicating
25 which terminals can use which frequency blocks for communications may be reported in advance to the terminals, for example, via a broadcast channel. Also, frequency blocks used by the terminals may be changed after communications are started. When a terminal
30 supporting the 10 MHz bandwidth performs communications using adjacent frequency blocks 1 and 2, the terminal receives control channels provided for frequency blocks 1 and 2 and thereby obtains scheduling information for

the 10 MHz bandwidth. When a terminal supporting the 15 MHz bandwidth performs communications using adjacent frequency blocks 1, 2, and 3, the terminal receives control channels provided for frequency blocks 1, 2, and 3 and thereby obtains scheduling information for the 15 MHz bandwidth. When a terminal supporting the 20 MHz bandwidth performs communications, the terminal receives control channels provided for all the frequency blocks and thereby obtains scheduling information for the 20 MHz bandwidth.

In FIG. 2, four discrete blocks labeled "control channel" are shown in each frequency block. This indicates that the control channels are mapped so as to be distributed across multiple resource blocks in the frequency block. Details of control channel mapping are described later.

FIG. 3A is a partial block diagram of a base station according to an embodiment of the present invention. The base station shown in FIG. 3A includes a frequency block allocation control unit 31; a frequency scheduling unit 32; a control signaling channel generating unit 33-1 and a data channel generating unit 34-1 for frequency block 1, ..., and a control signaling channel generating unit 33-M and a data channel generating unit 34-M for frequency block M; a broadcast channel (or paging channel) generating unit 35; a first multiplexing unit 1-1 for frequency block 1, ..., and a first multiplexing unit 1-M for frequency block M; a second multiplexing unit 37; a third multiplexing unit 38; an other channels generating unit 39; an inverse fast Fourier transform unit (IFFT) 40; and a cyclic prefix (CP) adding unit 41.

The frequency block allocation control unit 31

determines a frequency block(s) to be used by a terminal (a mobile terminal or a fixed terminal) based on information regarding the maximum supported bandwidth reported by the terminal. The frequency block allocation control unit 31 manages the correspondence between
5 respective terminals and frequency blocks and sends the correspondence information to the frequency scheduling unit 32. The correspondence between usable frequency blocks and terminals supporting different bandwidths may
10 be reported in advance to the terminals via a broadcast channel. For example, the frequency block allocation control unit 31 allows a user supporting the 5 MHz bandwidth to use any one or a specific one of frequency blocks 1 through 4. For a user supporting the 10 MHz
15 bandwidth, the frequency block allocation control unit 31 allows the use of two adjacent frequency blocks, i.e., frequency blocks "1 and 2", "2 and 3", or "3 and 4". The frequency block allocation control unit 31 may allow the user to use any one or a specific one of the
20 combinations. For a user supporting the 15 MHz bandwidth, the frequency block allocation control unit 31 allows the use of three adjacent frequency blocks, i.e., frequency blocks "1, 2, and 3" or "2, 3, and 4". The frequency block allocation control unit 31 may allow the
25 user to use any one or a specific one of the combinations. For a user supporting the 20 MHz bandwidth, the frequency block allocation control unit 31 allows the use of all frequency blocks. As described later, frequency blocks allowed to be used by a user may be
30 changed after communications are started according to a frequency hopping pattern.

The frequency scheduling unit 32 performs frequency scheduling for each of the frequency blocks.

The frequency scheduling unit 32 performs frequency scheduling for each frequency block based on channel quality indicators (CQIs) reported by terminals for respective resource blocks such that the resource blocks
5 are allocated preferentially to terminals with good channel conditions, and generates scheduling information based on the scheduling results.

The control signaling channel generating unit 33-1 for frequency block 1 forms control signaling
10 channels for reporting scheduling information of frequency block 1 to terminals using only resource blocks within frequency block 1. Similarly, each of the control signaling channel generating units 33 for other frequency blocks forms control signaling channels for
15 reporting scheduling information of the corresponding frequency block to terminals using only resource blocks within the corresponding frequency block.

The data channel generating unit 34-1 for frequency block 1 generates data channels each of which
20 is to be transmitted using one or more resource blocks in frequency block 1. Frequency block 1 may be shared by one or more terminals (users). Therefore, in this example, the data channel generating unit 34-1 for frequency block 1 includes N data channel generating
25 units 1-1 through 1-N. Similarly, each of the data channel generating units 34 for other frequency blocks generates data channels for terminals sharing the corresponding frequency block.

The first multiplexing unit 1-1 for frequency
30 block 1 multiplexes signals to be transmitted using frequency block 1. This multiplexing includes at least frequency division multiplexing. Multiplexing of the control signaling channels and the data channels is

described later in more detail. Similarly, each of the first multiplexing units 1 for other frequency blocks multiplexes control signaling channels and data channels to be transmitted using the corresponding frequency
5 block.

The second multiplexing unit 37 changes positional relationships of the first multiplexing units 1-x ($x=1, \dots, M$) on the frequency axis according to a hopping pattern. Details of this process are described
10 in a second embodiment.

The broadcast channel (or paging channel) generating unit 35 generates broadcast information such as office data to be reported to terminals covered by the base station. The broadcast information may include
15 information indicating the correspondence between maximum supported bandwidths of terminals and usable frequency blocks. If the usable frequency blocks are to be varied, the broadcast information may also include information specifying a hopping pattern indicating how
20 the usable frequency blocks are varied. A paging channel may be transmitted using the same frequency band as that used for the broadcast channel or using frequency blocks used by the respective terminals.

The other channels generating unit 39
25 generates channels other than control signaling channels and data channels. For example, the other channels generating unit 39 generates a pilot channel.

The third multiplexing unit 38 multiplexes control signaling channels and data channels of the
30 frequency blocks, a broadcast channel, and/or other channels as necessary.

The inverse fast Fourier transform unit 40 inverse-fast-Fourier-transforms a signal output from the

third multiplexing unit 38 and thereby modulates the signal according to OFDM.

The cyclic prefix (CP) adding unit 41 generates transmission symbols by attaching guard intervals to the OFDM-modulated symbols. A transmission symbol is, for example, generated by duplicating a series of data at the end (or head) of an OFDM-modulated symbol and attaching the duplicated data to the head (or end) of the OFDM-modulated symbol.

FIG. 3B shows components following the CP adding unit 41 shown in FIG. 3A. As shown in FIG. 3B, an RF transmission circuit performs digital-analog conversion, frequency conversion, and band limitation on the symbols with the guard intervals, and a power amplifier amplifies the symbols to an appropriate power level. Then, the symbols are transmitted via a duplexer and a transceiver antenna.

In this embodiment, it is assumed that the base station performs antenna diversity reception using two antennas, although this feature is not essential for the present invention. An uplink signal received by the two antennas is input to an uplink signal receiving unit.

FIG. 4A is a drawing illustrating signal processing components for one frequency block (xth frequency block). In FIG. 4A, "x" indicates an integer greater than or equal to 1 and less than or equal to M. Signal processing components for frequency block x include a control signaling channel generating unit 33-x, a data channel generating unit 34-x, multiplexing units 43-A, 43-B, ..., and a multiplexing unit 1-x. The control signaling channel generating unit 33-x includes a general control channel generating unit 41 and one or more specific control channel generating units 42-A, 42-

B, ...

The general control channel generating unit 41 performs channel coding and multilevel modulation on a general control channel (may also be called general control information), which is a part of the control signaling channels and to be decoded and demodulated by all terminals using the corresponding frequency block, and outputs the general control channel.

Each of the specific control channel generating units 42 performs channel coding and multilevel modulation on a specific control channel (may also be called specific control information), which is a part of the control signaling channels and to be decoded and demodulated by a terminal to which one or more resource blocks in the corresponding frequency block are allocated, and outputs the specific control channel.

The data channel generating unit 34-x includes data channel generating units x-A, x-B, ... that, respectively, perform channel coding and multilevel modulation on data channels for terminals A, B, ... Information regarding the channel coding and the multilevel modulation is included in the specific control channels described above.

The multiplexing units 43 map specific control channels and data channels of respective terminals to resource blocks allocated to the terminals.

As described above, the general control channel generating unit 41 encodes (and modulates) the general control channel and the specific control channel generating units 42 encode (and modulate) the respective specific control channels. Accordingly, as schematically shown in FIG. 6, the general control channel of this embodiment includes sets of information for all users

who are allocated frequency block x and the sets of information are collectively error-correction-coded.

Alternatively, the general control channel may be error-correction-coded for each user. In this case, a
5 user cannot uniquely identify one of error-correction-coded blocks that includes information for the user. Therefore, the user has to decode all of the blocks. With this method, because encoding is performed for each user, it is comparatively easy to add or change users.
10 Each user has to decode and demodulate the sets of information for all users in the general control channel.

Meanwhile, the specific control channels include only information for respective users to which resource blocks are actually allocated and are therefore
15 error-correction-coded for the respective users. Whether a resource block(s) has been allocated to a user can be determined by decoding and demodulating the general control channel. Therefore, only users who are allocated resource blocks have to decode the specific control
20 channels. The channel coding rates and modulation schemes for the specific control channels are changed during communications as needed. On the other hand, the channel coding rate and the modulation scheme for the general control channel may be fixed. Still, however, it
25 is preferable to perform transmission power control (TPC) for the general control channel to achieve a certain level of signal quality. Error-correction-coded specific control channels are transmitted using resource blocks providing good channel conditions. Therefore, the
30 amount of downlink data may be reduced to some extent by puncturing.

FIG. 5A shows types of downlink control signaling channels and exemplary information items of

the respective downlink control signaling channels. Downlink control signaling channels include a broadcast channel (BCH), a dedicated L3 signaling channel (upper-layer control channel), and an L1/L2 control channel
5 (lower-layer control channel). The L1/L2 control channel may include uplink data transmission information in addition to downlink data transmission information. Information items to be transmitted by the respective channels are described below.

10

(Broadcast Channel)

The broadcast channel is used to report information that is unique to a cell or information that changes at long intervals to communication terminals
15 (either mobile terminals or fixed terminals; may also be called user devices). For example, information that changes at an interval of 1000 ms (1 s) may be reported as broadcast information. Broadcast information may also include a transport format of a downlink L1/L2 control
20 channel, the maximum number of multiplexed users, resource block arrangement information, and MIMO scheme information.

The transport format is specified by a data modulation scheme and a channel coding rate. Since a
25 channel coding rate can be uniquely determined based on a data modulation scheme and a data size, the data size may be reported instead of the channel coding rate.

The maximum number of multiplexed users indicates the number of users that can be multiplexed
30 within one TTI using one or more of FDM, CDM, and TDM. The same maximum number of multiplexed users may be specified for uplink and downlink, or different numbers may be specified for uplink and downlink.

The resource block arrangement information indicates positions of resource blocks used in a cell on the frequency and time axes. In this embodiment, two types of frequency division multiplexing (FDM) schemes are used: localized FDM and distributed FDM. In localized FDM, a consecutive frequency band locally-concentrated on the frequency axis is allocated preferentially to each user having good channel conditions. Localized FDM is suitable, for example, for communications of users with low mobility and for high-quality, high-volume data transmission. In distributed FDM, a downlink signal is generated such that it includes multiple intermittent frequency components distributed across a wide frequency band. Distributed FDM is suitable, for example, for communications of users with high mobility and for periodic transmission of small-size data such as voice packets (VoIP). Thus, frequency resources are allocated as a consecutive frequency band or discrete frequency components to each user based on the resource block arrangement information according to either of the FDM schemes.

The upper half of FIG. 5B illustrates an example of localized FDM. In this example, when a resource is identified by a localized resource block number "4", it corresponds to physical resource block 4. The lower half of FIG. 5B illustrates an example of distributed FDM. In this example, when a resource is identified by a distributed resource block number "4", it corresponds to left halves of physical resource blocks 2 and 8. In the lower half of FIG. 5B, each physical resource block is divided into two. However, the numbering and the number of divisions of resource blocks in distributed FDM may vary from cell to cell.

For this reason, the resource block arrangement information is reported via a broadcast channel to communication terminals in each cell.

The MIMO scheme information is reported if the
5 base station is equipped with multiple antennas and indicates whether single-user multi-input multi-output (SU-MIMO) or multi-user MIMO (MU-MIMO) is used. In SU-MIMO, a base station with multiple antennas communicates with one communication terminal with multiple antennas.
10 Meanwhile, in MU-MIMO, a base station with multiple antennas communicates with plural communication terminals at the same time.

(Dedicated L3 Signaling Channel)

15 The dedicated L3 signaling channel is also used to report information that changes at long intervals, for example, at an interval of 1000 ms, to communication terminals. While the broadcast channel is sent to all communication terminals in a cell, the
20 dedicated L3 signaling channel is sent only to specific communication terminals. The dedicated L3 signaling channel includes information on a type of FDM and persistent scheduling information. The dedicated L3 signaling channel may be categorized as a specific
25 control channel.

The type of FDM indicates whether localized FDM or distributed FDM is used for each of selected communication terminals.

The persistent scheduling information is
30 reported when persistent scheduling is employed and includes transport formats (data modulation schemes and channel coding rates) of uplink or downlink data channels and information on resource blocks to be used.

(L1/L2 Control Channel)

The downlink L1/L2 control channel may include uplink data transmission information in addition to
5 downlink data transmission information. Downlink data transmission information may be classified into part 1, part 2a, and part 2b. Part 1 and part 2a may be categorized as a general control channel and part 2b may be categorized as a specific control channel.

10 (Part 1)

Part 1 includes a paging indicator (PI). Each communication terminal can determine whether it is being paged by demodulating the paging indicator.

(Part 2a)

15 Part 2a includes resource allocation information for a downlink data channel, an allocation interval, and MIMO information.

The resource allocation information for a downlink data channel identifies a resource block(s)
20 used for the downlink data channel. For the identification of resource blocks, various methods, such as a bitmap scheme and a tree numbering scheme, known in the relevant technical field may be used.

The allocation interval indicates a period of
25 time for which the downlink data channel is transmitted continuously. The resource allocation can be changed as frequently as every TTI. However, to reduce the overhead, a data channel may be transmitted according to the same resource allocation for plural TTIs.

30 The MIMO information is reported when a MIMO scheme is used for communications and indicates, for example, the number of antennas and the number of streams. The number of streams may also be called the

number of information sequences.

Although it is not essential, the whole or a part of user identification information may also be included in part 2a.

5 (Part 2b)

Part 2b includes precoding information for a MIMO scheme, a transport format of a downlink data channel, hybrid automatic repeat request (HARQ) information, and CRC information.

10 The precoding information for a MIMO scheme indicates weighting factors applied to respective antennas. Directional characteristics of communication signals can be adjusted by adjusting the weighting factors to be applied to the respective antennas.

15 The transport format of a downlink data channel is specified by a data modulation scheme and a channel coding rate. Since a channel coding rate can be uniquely determined based on a data modulation scheme and a data size, the data size or a payload size may be reported instead of the channel coding rate.

20 The hybrid automatic repeat request (HARQ) information includes information necessary for retransmission control of downlink packets. More specifically, the HARQ information includes a process number, redundancy version information indicating a packet combination scheme, and a new data indicator indicating whether a packet is a new packet or a retransmission packet.

25 The CRC information is reported when cyclic redundancy checking is employed for error detection and indicates CRC detection bits convolved with user identification information (UE-ID).

Uplink data transmission information may be

classified into part 1 through part 4. Basically, uplink data transmission information is categorized as a general control channel. However, for communication terminals that are allocated resources for downlink data channels, the uplink data transmission information may be transmitted as specific control channels.

(Part 1)

Part 1 includes acknowledgement information for a previous uplink data channel. The acknowledgement information indicates either acknowledge (ACK) indicating that no error is detected in a packet or a detected error is within an acceptable range, or negative acknowledge (NACK) indicating an error out of the acceptable range is detected in a packet.

(Part 2)

Part 2 includes resource allocation information for a future uplink data channel, and a transport format, transmission power information, and CRC information for the uplink data channel.

The resource allocation information identifies a resource block(s) usable for the transmission of the uplink data channel. For the identification of resource blocks, various methods, such as a bitmap scheme and a tree numbering scheme, known in the relevant technical field may be used.

The transport format of the uplink data channel is specified by a data modulation scheme and a channel coding rate. Since a channel coding rate can be uniquely determined based on a data modulation scheme and a data size, the data size or a payload size may be reported instead of the channel coding rate.

The transmission power information indicates a transmission power level to be used for the transmission

of the uplink data channel.

The CRC information is reported when cyclic redundancy checking is employed for error detection and indicates CRC detection bits convolved with user
5 identification information (UE-ID). In a response signal (downlink L1/L2 control channel) to a random access channel (RACH), a random ID of the RACH preamble may be used as a UE-ID.

(Part 3)

10 Part 3 includes transmission timing control bits. The transmission timing control bits are used to synchronize communication terminals in a cell.

(Part 4)

Part 4 includes transmission power information
15 indicating a transmission power level of a communication terminal. Specifically, the transmission power information indicates a transmission power level to be used by a communication terminal, which is not allocated resources for uplink data channel transmission, to
20 report a downlink CQI.

FIG. 4B, like FIG. 4A, shows signal processing components for one frequency block. FIG. 4B is different from FIG. 4A in that examples of control information are provided. In FIG. 4B, the same reference numbers are
25 used for components corresponding to those in FIG. 4A. "Allocated resource block mapping" in FIG. 4B indicates that channels are mapped to one or more resource blocks allocated to a selected communication terminal. "Other resource block mapping" indicates that channels are
30 mapped across the entire frequency block including multiple resource blocks. Uplink data transmission information (parts 1 through 4) in the L1/L2 control channel is transmitted as a specific control channel

using resources allocated for a downlink data channel if available or transmitted as a general control channel using the entire frequency block if no resource is allocated for a downlink data channel.

5 FIG. 7A is a drawing illustrating exemplary mapping of data channels and control channels. This example shows mapping of channels within one frequency block and one subframe and roughly corresponds to an output from the first multiplexing unit 1-x (except that
10 channels such as a pilot channel are multiplexed by the third multiplexing unit 38). One subframe may correspond to one transmission time interval (TTI) or to multiple TTIs. In this example, a frequency block includes seven resource blocks RB1 through RB7. The seven resource
15 blocks are allocated to terminals with good channel conditions by the frequency scheduling unit 32 shown in FIG. 3A.

 Normally, a general control channel, a pilot channel, and data channels are time-division-multiplexed.
20 The general control channel is mapped to frequency components distributed across the entire frequency block. In other words, the general control channel is distributed across a frequency band composed of seven resource blocks. In this example, the general control
25 channel and other control channels (excluding the specific control channels) are frequency-division-multiplexed. The other control channels, for example, include a synchronization channel. In the example shown in FIG. 7A, the general control channel and the other
30 control channels are frequency-division-multiplexed such that each of the channels is mapped to multiple frequency components arranged at intervals. Such a multiplexing scheme is called distributed frequency

division multiplexing (FDM). The frequency components allocated to the respective channels may be arranged at the same intervals or at different intervals. In either case, it is necessary to distribute the general control
5 channel across the entire frequency block.

In this example, the pilot channel is also mapped across the entire frequency block. Mapping a pilot channel to a wide frequency range as shown in FIG. 7A is preferable to accurately perform channel
10 estimation for various frequency components.

In FIG. 7A, resource blocks RB1, RB2, and RB4 are allocated to user 1 (UE1), resource blocks RB3, RB5, and RB6 are allocated to user 2 (UE2), and resource block RB7 is allocated to user 3 (UE3). As described
15 above, this resource block allocation information is included in the general control channel. A specific control channel for user 1 is mapped to the beginning of resource block RB1 allocated to user 1. A specific control channel for user 2 is mapped to the beginning of
20 resource block RB3 allocated to user 2. A specific control channel for user 3 is mapped to the beginning of resource block RB7 allocated to user 3. Note that, in FIG. 7A, the sizes of the portions occupied by the respective specific control channels of users 1, 2, and
25 3 are not equal. This indicates that the amount of information of the specific control channel may vary depending on the user. The specific control channel is mapped locally to resources within a resource block allocated to a data channel. In contrast with
30 distributed FDM where a channel is mapped to frequency components distributed across multiple resource blocks, this mapping scheme is called localized frequency division multiplexing (FDM).

FIG. 7B shows another exemplary mapping of specific control channels. In FIG. 7A, the specific control channel for user 1 (UE1) is mapped only to resource block RB1. In FIG. 7B, the specific control channel for user 1 is mapped to frequency components discretely distributed across resource blocks RB1, RB2, and RB4 (across all the resource blocks allocated to user 1) by distributed FDM. The specific control channel for user 2 (UE2) is also mapped to all resource blocks RB3, RB5, and RB6 in a manner different from that shown in FIG. 7A. The specific control channel and the shared data channel of user 2 are time-division-multiplexed. Thus, a specific control channel and a shared data channel of a user may be multiplexed in the whole or a part of one or more resource blocks allocated to the user by time division multiplexing (TDM) and/or frequency division multiplexing (localized FDM or distributed FDM). Mapping a specific control channel across two or more resource blocks makes it possible to achieve frequency diversity gain also for the specific control channel and thereby to improve the reception quality of the specific control channel.

FIG. 7C shows exemplary multiplexing schemes. In the above example, sets of general control information are multiplexed by distributed FDM. However, any appropriate multiplexing scheme such as code division multiplexing (CDM) or time division multiplexing (TDM) may be used. FIG. 7C (1) shows an example of distributed FDM. In FIG. 7C (1), discrete frequency components identified by numbers 1, 2, 3, and 4 are used to properly orthogonalize user signals. Discrete frequency components may be arranged at regular intervals as exemplified or at irregular intervals. Also,

different arrangement rules may be used for neighboring cells to randomize the interference when transmission power control is employed. FIG. 7C (2) shows an example of code division multiplexing (CDM). In FIG. 7C (2),
5 codes 1, 2, 3, and 4 are used to properly orthogonalize user signals. FIG. 7C (3) shows an example of distributed FDM where the number of multiplexed users is three. In FIG. 7C (3), discrete frequency components are redefined by numbers 1, 2, and 3 to properly
10 orthogonalize user signals. If the number of multiplexed users is less than the maximum number, the base station may increase the transmission power of downlink control channels as shown in FIG. 7C (4). A hybrid multiplexing scheme of CDM and FDM may also be used.

15 FIG. 8A is a partial block diagram of a mobile terminal according to an embodiment of the present invention. The mobile terminal shown in FIG. 8A includes a carrier frequency tuning unit 81, a filtering unit 82, a cyclic prefix (CP) removing unit 83, a fast Fourier
20 transform unit (FFT) 84, a CQI measuring unit 85, a broadcast channel (or paging channel) decoding unit 86, a general control channel decoding unit 87, a specific control channel decoding unit 88, and a data channel decoding unit 89.

25 The carrier frequency tuning unit 81 appropriately adjusts the center frequency of the reception band so as to be able to receive a signal in a frequency block allocated to the terminal.

30 The filtering unit 82 filters the received signal.

The cyclic prefix removing unit 83 removes guard intervals from the received signal and thereby extracts effective symbols from received symbols.

The fast Fourier transform unit (FFT) 84 fast-Fourier-transforms information in the effective symbols and demodulates the information according to OFDM.

5 The CQI measuring unit 85 measures the received power level of a pilot channel in the received signal and feeds back the measurement as a channel quality indicator (CQI) to the base station. The CQI is measured for each resource block in the frequency block and all measured CQIs are reported to the base station.

10 The broadcast channel (or paging channel) decoding unit 86 decodes a broadcast channel. The broadcast channel (or paging channel) decoding unit 86 also decodes a paging channel if it is included.

15 The general control channel decoding unit 87 decodes a general control channel in the received signal and thereby extracts scheduling information. The scheduling information includes information indicating whether resource blocks are allocated to a shared data channel for the terminal. If resource blocks are
20 allocated, the scheduling information also includes information indicating the corresponding resource block numbers.

The specific control channel decoding unit 88 decodes a specific control channel in the received
25 signal. The specific control channel includes a data modulation scheme, a channel coding rate, and HARQ information for the shared data channel.

The data channel decoding unit 89 decodes the shared data channel in the received signal based on
30 information extracted from the specific control channel. The mobile terminal may report acknowledge (ACK) or negative acknowledge (NACK) to the base station according to the result of decoding.

FIG. 8B is also a partial block diagram of the mobile terminal of this embodiment. FIG. 8B is different from FIG. 8A in that examples of control information are provided. In FIG. 8B, the same reference numbers are
5 used for components corresponding to those in FIG. 8A. "Allocated resource block demapping" in FIG. 8B indicates that information mapped to one or more resource blocks allocated to the terminal is extracted. "Other resource block demapping" indicates that
10 information mapped across the entire frequency block including multiple resource blocks is extracted.

FIG. 8C shows components related to a receiving unit of the mobile terminal shown in FIG. 8A. In this embodiment, it is assumed that the mobile
15 terminal performs antenna diversity reception using two antennas, although this feature is not essential for the present invention. Downlink signals received by the two antennas are input to RF reception circuits 81 and 82. Cyclic prefix removing units 83 remove guard intervals
20 (cyclic prefixes) from the signals, and fast Fourier transform (FFT) units 84 fast-Fourier-transform the signals. Then, the signals are combined by an antenna diversity combining unit. The combined signal is input to the respective decoding units shown in FIG. 8A or to
25 a separating unit shown in FIG. 8B.

FIG. 9A is a flowchart showing an exemplary process according to an embodiment of the present invention. In the descriptions below, it is assumed that a user carrying a mobile terminal UE1 supporting a
30 MHz bandwidth has entered a cell or a sector using a 20 MHz bandwidth for communications. It is also assumed that the minimum frequency band of the communication system is 5 MHz and the entire system frequency band is

divided into four frequency blocks 1 through 4 as shown in FIG. 2.

In step S11, the terminal UE1 receives a broadcast channel from the base station and determines frequency blocks that the terminal UE1 is allowed to use. The broadcast channel is, for example, transmitted using a 5 MHz band including the center frequency of the 20 MHz band. This enables terminals supporting different bandwidths to easily receive the broadcast channel. For example, the base station allows a user communicating with a 10 MHz bandwidth to use a combination of two adjacent frequency blocks, i.e., frequency blocks 1 and 2, 2 and 3, or 3 and 4. The base station may allow the user to use any one or a specific one of the combinations. In this example, it is assumed that the terminal UE1 is allowed to use frequency blocks 2 and 3.

In step S12, the terminal UE1 receives a downlink pilot channel and measures the received signal quality for respective frequency blocks 2 and 3. The received signal quality is measured for each resource block in the respective frequency blocks and all measurements are reported as channel quality indicators (CQIs) to the base station.

In step S21, the base station performs frequency scheduling for each frequency block based on CQIs reported by the terminal UE1 and other terminals. In this example, a data channel for the terminal UE1 is transmitted using frequency blocks 2 and 3. This information is being managed by the frequency block allocation control unit 31 (see FIG. 3A).

In step S22, the base station generates control signaling channels for each frequency block according to scheduling information. The control

signaling channels include a general control channel and specific control channels.

In step S23, the base station transmits the control signaling channels and shared data channels of
5 the respective frequency blocks according to the scheduling information.

In step S13, the terminal UE1 receives signals transmitted via frequency blocks 2 and 3.

In step S14, the terminal UE1 separates the
10 general control channel from the control signaling channels received via frequency block 2, decodes the general control channel, and thereby extracts scheduling information. The terminal UE1 also separates the general control channel from the control signaling channels
15 received via frequency block 3, decodes the general control channel, and thereby extracts scheduling information. The scheduling information of each of frequency blocks 2 and 3 includes information indicating whether resource blocks are allocated to a shared data
20 channel for the terminal UE1. If resource blocks are allocated, the scheduling information also includes information indicating the corresponding resource block numbers. If no resource block is allocated to the shared data channel for the terminal UE1, the terminal UE1
25 returns to the standby mode and waits for the next control signaling channels. If resource blocks are allocated to a shared data channel for the terminal UE1, the terminal UE1 separates a corresponding specific control channel from the received signal and decodes the
30 specific control channel in step S15. The specific control channel includes a data modulation scheme, a channel coding rate, and HARQ information for the shared data channel.

In step S16, the terminal UE1 decodes the shared data channel in the received signal based on information extracted from the specific control channel. The mobile terminal may report acknowledge (ACK) or
5 negative acknowledge (NACK) to the base station according to the result of decoding. Thereafter, the above steps are repeated.

FIG. 9B is a drawing illustrating an exemplary method for reducing the amount of uplink data
10 transmission information. In step S1, the base station transmits a downlink L1/L2 control channel. As described above (particularly with reference to FIG. 7C), sets of control information for multiple communication terminals are multiplexed for transmission. Each communication
15 terminal demodulates the sets of control information in the L1/L2 control channel for itself and other communication terminals. Here, let us assume that control information including the UE-ID of a communication terminal is in the xth position in a
20 general control channel. The communication terminal demodulates the general control channel and identifies resources (e.g., resource blocks) allocated to the communication terminal based on allocation information in the general control channel.

25 In step S2, the communication terminal transmits (a packet of) an uplink data channel D ($t = \text{TTI } 1$) to the base station using the allocated resource blocks. Here, $t = \text{TTI } 1$ indicates time.

In step S3, the base station receives and
30 decodes the uplink data channel D ($t = \text{TTI } 1$) and determines whether any error is present. The determination result is indicated by ACK or NACK. Then, the base station reports the determination result via an

L1/L2 control channel to the communication terminal that has transmitted the uplink data channel D. According to the table shown in FIG. 5A, the determination result (acknowledgement information) belongs to part 1 of the uplink data transmission information. The base station also receives uplink channels from other communication terminals and transmits the acknowledgement information (ACK/NACK) to each of the other communication terminals. Accordingly, it is possible to enable each communication terminal to identify the corresponding acknowledgement information (ACK/NACK) for a previously transmitted uplink data channel by attaching user identification information (ID) to each part 1 (ACK/NACK) of the uplink data transmission information in the downlink L1/L2 control channel.

However, in this embodiment, the downlink L1/L2 control channel is transmitted without attaching identification information to part 1 information for each communication terminal to reduce the amount of control information. Instead, in this embodiment, the correspondence between part 1 information and an allocation number X used for part 2 information is maintained for each communication terminal. Here, let us assume that a multiplexing scheme as shown by FIG. 7C (1) is employed and an allocation number 3 ($X=3$) is used to report the part 2 information to the communication terminal UE1. In this case, the communication terminal UE1 demodulates resource allocation information with the allocation number 3 to identify a resource block(s) allocated for an uplink data channel and transmits the uplink data channel using the identified resource block. The part 1 information (ACK/NACK) for the uplink data channel is included in a resource with an allocation

number 3 in a downlink L1/L2 control channel to be transmitted at $t = \text{TTI } 1 + \alpha$. Here, α indicates a time period after which acknowledgement information is returned. In step S3 of FIG. 9B, this downlink L1/L2 control channel is transmitted.

In step S4, each communication terminal reads the part 1 information based on the allocation number X and the time period α to determine whether it is necessary to retransmit the uplink data channel D ($t = \text{TTI } 1$) transmitted at $t = \text{TTI } 1$.

Thus, in this embodiment, the one-to-one correspondence between the allocation number used in step S1 and the allocation number used in step S3 is maintained for each communication terminal. This method eliminates the need for the base station to attach user identification information to each part 1 (ACK/NACK) of the uplink data transmission information. In other words, this method makes it possible to reduce the amount of information of the downlink L1/L2 control channel generated in step S22 shown in FIG. 9A. Assuming that resources for uplink data channels are allocated to M communication terminals at time $t = \text{TTI } 1$, allocation numbers 1 through M are used. In this case, the number of sets of allocation information (part 2) in the uplink data transmission information and the number of destinations to which acknowledgement information (part 1) is to be transmitted at time $t = \text{TTI } 1 + \alpha$ are both M. Therefore, it is always possible to maintain the one-to-one correspondence between allocation numbers X.

Thus, it is possible to reduce the number of resources allocated in advance for transmission of downlink ACK/NACK by associating sets of uplink resource allocation information in a downlink control channel

with the resources used for transmission of downlink ACK/NACK. More specifically, it is possible to reduce the number of resources allocated in advance for downlink ACK/NACK by associating allocation numbers of parts 2 of the uplink data transmission information in a downlink control channel used for uplink resource allocation and allocation numbers of parts 1 of the uplink data transmission information that identify resources used to transmit downlink ACK/NACK for uplink data channels.

When resources are allocated to data channels without using a control signaling channel, a method used for retransmission or persistent scheduling may be employed.

When persistent scheduling is employed, resources for ACK/NACK are provided separately.

Alternatively, indexes of uplink resources, such as resource units, for data channels may be associated with resources for downlink ACK/NACK. With this method, however, the number of resources used for ACK/NACK is determined according to the number of multiplexed users. For example, when the transmission bandwidth is 10 MHz and space division multiple access (SDMA) is performed by two users, $50 \times 2 = 100$ RUs are required.

Therefore, to reduce the number of resources to be reserved, it is preferable to associate sets of uplink resource allocation information in a downlink control channel with resources used for transmission of downlink ACK/NACK.

<SECOND EMBODIMENT>

FIG. 10 is a drawing illustrating an example

of frequency hopping. In FIG. 10, a frequency band allocated to the communication system has a bandwidth of 20 MHz and includes four frequency blocks with the minimum bandwidth of 5 MHz. In this example, it is
5 assumed that the communication system can accommodate 40 users supporting a 5 MHz bandwidth, 20 users supporting a 10 MHz bandwidth, and 10 users supporting a 20 MHz bandwidth.

The users supporting the 20 MHz bandwidth can
10 always use all frequency blocks 1 through 4. Meanwhile, users 1 through 10 of 40 users supporting only the 5 MHz bandwidth are allowed to use only frequency block 1 at time t , to use only frequency block 2 at time $t+1$, and to use only frequency block 3 at time $t+2$. Similarly,
15 users 11 through 20 supporting the 5 MHz bandwidth are allowed to use frequency blocks 2, 3, and 4 at time t , $t+1$, and $t+2$, respectively. Users 21 through 30 supporting the 5 MHz bandwidth are allowed to use frequency blocks 3, 4, and 1 at time t , $t+1$, and $t+2$,
20 respectively. Users 31 through 40 supporting the 5 MHz bandwidth are allowed to use frequency blocks 4, 1, and 2 at time t , $t+1$, and $t+2$, respectively. Also, users 1 through 10 of 20 users supporting only the 10 MHz bandwidth are allowed to use only frequency blocks 1 and
25 2 at time t , to use only frequency blocks 3 and 4 at time $t+1$, and to use only frequency blocks 1 and 2 at time $t+2$. Similarly, users 11 through 20 supporting the 10 MHz bandwidth are allowed to use frequency blocks 3 and 4, frequency blocks 1 and 2, and frequency blocks 3
30 and 4 at time t , $t+1$, and $t+2$, respectively.

Such a frequency hopping pattern is reported beforehand to the users via a broadcast channel or by any other method. Here, multiple frequency hopping

patterns may be predefined and a pattern number indicating one of the frequency hopping patterns to be used may be reported to the users. This method makes it possible to report the frequency hopping pattern to
5 users by using a small number of bits. When it is possible to select frequency blocks used for communications as in this embodiment, it is preferable to change the frequency blocks used for communications after the communications are started in order to
10 equalize the communication quality between users and frequency blocks. If frequency hopping is not performed and the communication quality varies from frequency block to frequency block, a certain user may have to communicate with poor quality all the time. Meanwhile,
15 with frequency hopping, even if the communication quality of a user is poor at a time point, it can be expected that the communication quality of the user becomes better at another time point.

With the exemplary frequency hopping pattern
20 shown in FIG. 10, the 5 MHz band or the 10 MHz band used by a user is shifted one by one to the right. However, any other type of hopping pattern may be used as long as the hopping pattern is known to the sending and receiving ends.

25

<THIRD EMBODIMENT>

In a third embodiment of the present invention, methods of transmitting a paging channel in addition to a control signaling channel are described.

30 FIG. 11 is a drawing illustrating an exemplary process (flowchart on the left side) and a frequency band (on the right side) used in the process according to an embodiment of the present invention. In step S1,

the base station transmits a broadcast channel to users covered by the base station. As shown in FIG. 11 (1), the broadcast channel is transmitted using the minimum bandwidth including the center frequency of the entire frequency band. Broadcast information reported by the
5 broadcast channel includes the correspondence between bandwidths supported by the users and usable frequency blocks.

In step S2, a user (e.g., UE1) enters the
10 standby mode in a specified frequency block (e.g., frequency block 1). The user UE1 adjusts the reception band so as to be able to receive a signal in frequency block 1 that the user UE1 is allowed to use. In this embodiment, in addition to a control signaling channel
15 for the user UE1, a paging channel for the user UE1 is also transmitted using frequency block 1. If it is determined that the user UE1 is being paged by the paging channel, the process goes to step S3.

In step S3, the user UE1 receives a data
20 channel via a specified frequency block according to scheduling information. Then, the user UE1 enters the standby mode again.

FIG. 12 is a drawing illustrating another exemplary process (flowchart on the left side) and a frequency band (on the right side) used in the process according to an embodiment of the present invention. Similar to the process shown in FIG. 11, in step S1, the base station transmits a broadcast channel using the minimum bandwidth including the center frequency of the
25 entire frequency band (FIG. 12 (1)). Also in this example, it is assumed that the user UE1 is allowed to use frequency block 1.

In step S2, the user UE1 enters the standby

mode. Different from the example of FIG. 11, the user UE1 does not adjust the reception band at this stage. Therefore, the user UE1 waits for a paging channel in the same frequency band as that used to receive the
5 broadcast channel (FIG. 12 (2)).

In step S3, after receiving the paging channel, the user UE1 switches to frequency block 1 allocated to itself, receives a control signaling channel, and communicates according to scheduling information (FIG.
10 12 (3)). Then, the user UE1 enters the standby mode again.

In the example of FIG. 11, the user UE1 switches to frequency block 1 as soon as it enters the standby mode. Meanwhile, in the example of FIG. 12, the
15 user UE1 does not switch to frequency block 1 when entering the standby mode, but switches to frequency block 1 after the user UE1 is paged. In other words, in the method of FIG. 11, each user waits for a signal in a frequency block allocated to the user; and in the method
20 of FIG. 12, all users wait for a signal in the same frequency band. Compared with the method of FIG. 12, the method of FIG. 11 may be preferable to equally use the entire frequency resources. Further, a neighboring cell search for determining whether handover is necessary is
25 performed using the minimum bandwidth around the center frequency of the entire frequency band. Accordingly, to reduce the number of times frequency tuning is performed, it is preferable to use the same frequency band for reception during the standby mode and for the cell
30 search as shown in FIG. 12.

<FOURTH EMBODIMENT>

To improve the received signal quality of

control channels, it is preferable to perform link adaptation. In a fourth embodiment of the present invention, transmission power control (TPC) and adaptive modulation and coding (AMC) are used to perform link adaptation. FIG. 13 is a drawing illustrating an example of transmission power control where transmission power of downlink channels is controlled to achieve desired reception quality. Referring to FIG. 11, a high transmission power level is used to transmit a downlink channel to user 1 because user 1 is away from the base station and its channel conditions are expected to be poor. Meanwhile, channel conditions of user 2 close to the base station are expected to be good. In this case, using a high transmission power level to transmit a downlink channel to user 2 may increase the received signal quality at user 2 but may also increase interference with other users. Because the channel conditions of user 2 are good, it is possible to achieve desired reception quality with a low transmission power level. Therefore, a downlink channel for user 2 is transmitted using a comparatively low transmission power level. When only transmission power control is employed, a fixed combination of a modulation scheme and a channel coding scheme known to the sending and receiving ends is used. Accordingly, under the transmission power control, it is not necessary to report modulation and channel coding schemes to the users for demodulation of channels.

FIG. 14 is a drawing illustrating an example of adaptive modulation and coding (AMC) where one or both of the modulation scheme and the coding scheme are adaptively changed according to channel conditions to achieve desired reception quality. Assuming that the transmission power of the base station is constant, it

is expected that channel conditions of user 1 away from the base station are poor. In such a case, the modulation level and/or the channel coding rate is set at a small value. In the example shown in FIG. 14, QPSK
5 is used as the modulation scheme for user 1 and therefore two bits of information are transmitted per symbol. On the other hand, the channel conditions of user 2 close to the base station are expected to be good and therefore, the modulation level and/or the channel
10 coding rate is set at a large value. In FIG. 14, 16QAM is used as the modulation scheme for user 2 and therefore four bits of information are transmitted per symbol. This method makes it possible to achieve desired reception quality for a user with poor channel
15 conditions by improving the reliability, and to achieve desired reception quality as well as increase the throughput for a user with good channel conditions. When adaptive modulation and coding is employed, modulation information including the modulation scheme, the coding
20 scheme, and the number of symbols of a received channel is necessary to demodulate the channel. Therefore, it is necessary to report the modulation information to the receiving end. Also, with the above method, the number of bits transmitted per symbol varies depending on the
25 channel conditions. In other words, a small number of symbols are necessary to transmit information when channel conditions are good, but a large number of symbols are necessary to transmit information when channel conditions are poor.

30 In the fourth embodiment of the present invention, transmission power control is performed for a general control channel to be decoded by users in general, and transmission power control and/or adaptive

modulation and coding is performed for specific control channels to be decoded by users who are allocated resource blocks. The fourth embodiment may be implemented by any one of the three methods described
5 below.

(1) TPC-TPC

In a first method, only transmission power control is performed for the general control channel and the specific control channels. In this method, a
10 properly received channel can be demodulated without receiving modulation information including the modulation scheme, coding rate, etc. in advance because they are fixed. The general control channel is distributed across a frequency block and is therefore
15 transmitted using the same transmission power level throughout the entire frequency range. Meanwhile, a specific control channel for a user is mapped to resources within a resource block(s) allocated to the user. Therefore, transmission power of specific control
20 channels may be adjusted for respective users who are allocated resource blocks to improve the received signal quality of the users. Taking FIGs. 7A and 7B as an example, the general control channel may be transmitted with a transmission power level P_0 , the specific control
25 channel for user 1 (UE1) may be transmitted with a transmission power level P_1 suitable for user 1, the specific control channel for user 2 (UE2) may be transmitted with a transmission power level P_2 suitable for user 2, and the specific control channel for user 3
30 (UE3) may be transmitted with a transmission power level P_3 suitable for user 3. In this case, shared data channels may be transmitted using the corresponding transmission power levels P_1 , P_2 , and P_3 or a different

transmission power level P_0 .

As described above, the general control channel is decoded by all users. However, the purpose of the general control channel is to report the presence of data and scheduling information for the data to users to which resource blocks are allocated. Therefore, the transmission power used to transmit the general control channel may be adjusted to achieve desired reception quality for the users who are allocated resource blocks. For example, in FIGs. 7A and 7B, if all users 1, 2, and 3 who are allocated resource blocks are located near the base station, the transmission power level P_0 for the general control channel may be set at a comparatively small value. In this case, a user other than users 1, 2, and 3 who is located, for example, at a cell edge may not be able to decode the general control channel properly. However, this does not cause any practical problem because no resource block is allocated to the user.

(2) TPC-AMC

In a second method, transmission power control is performed for the general control channel and adaptive modulation and coding is performed for the specific control channels. When AMC is employed, it is basically necessary to provide users with modulation information in advance. In this method, modulation information for the specific control channels is included in the general control channel. Therefore, each user receives, decodes, and demodulates the general control channel first, and determines whether data for the user are present. If data for the user are present, the user extracts scheduling information as well as modulation information including a modulation scheme, a

coding scheme, and the number of symbols of the specific control channel. Then, the user demodulates the specific control channel according to the scheduling information and the modulation information, thereby obtaining
5 modulation information of a shared data channel, and demodulates the shared data channel based on the modulation information.

Control channels require lower throughput compared with shared data channels. Therefore, the number
10 of combinations of modulation and coding schemes for AMC of the specific control channel may be smaller than that used for the shared data channel. For example, for AMC of the specific control channel, QPSK is statically used as the modulation scheme and the coding rate may be selected
15 from $7/8$, $3/4$, $1/2$, and $1/4$.

The second method enables all users to receive the general control channel with a certain level of quality as well as to improve the reception quality of the specific control channels. This is achieved by
20 mapping specific control channels to resource blocks providing good channel conditions for respective selected communication terminals and by using appropriate modulation schemes and/or coding schemes for the respective communication terminals. Thus, in this
25 method, adaptive modulation and coding is applied to specific control channels to improve their reception quality.

When a very limited number of combinations of modulation schemes and channel coding rates are used, a
30 receiving end may be configured to try all of the combinations to demodulate a specific control channel and to use properly demodulated information. This approach makes it possible to perform a certain level of

AMC without reporting modulation information to users in advance.

(3) TPC-TPC/AMC

In a third method, transmission power control
5 is performed for the general control channel, and both
transmission power control and adaptive modulation and
coding are performed for the specific control channels.
As described above, when AMC is employed, it is
basically necessary to provide users with modulation
10 information in advance. Also, it is preferable to
provide a large number of combinations of modulation
schemes and channel coding rates to achieve desired
reception quality even when the degree of fading is high.
However, using a large number of combinations
15 complicates the process of determining an appropriate
combination, increases the amount of information needed
to report the determined combination, and increases the
processing workload and overhead. In the third method,
reception quality is maintained by a combination of TPC
20 and AMC. In other words, it is not necessary to
compensate for the entire fading solely by AMC. For
example, a modulation scheme and a coding scheme that
nearly achieve desired quality are selected and then
transmission power is adjusted to fully achieve the
25 desired quality under the selected modulation scheme and
coding scheme. This method makes it possible to reduce
the number of combinations of modulation schemes and
channel coding schemes.

In all of the three methods described above,
30 only transmission power control is performed for the
general control channel. Therefore, the user can receive
the general control channel with desired reception
quality and also can easily obtain control information

from the general control channel. Unlike AMC, transmission power control does not change the amount of information transmitted per symbol and therefore the general control channel can be easily transmitted using
5 a fixed format. Also, because the general control channel is distributed across the entire frequency block or multiple resource blocks, high frequency diversity gain can be expected. This in turn makes it possible to achieve enough reception quality by simple transmission
10 power control where a long-period average of the transmission power level is adjusted. However, performing only transmission power control for the general control channel is not an essential feature of the present invention. For example, the transport format
15 of the general control channel may be changed at long intervals and reported via a broadcast channel.

Meanwhile, including AMC control information (modulation information) for specific control channels in the general control channel makes it possible to
20 perform AMC for the specific control channels and thereby makes it possible to improve the transmission efficiency and quality of the specific control channels. While the number of symbols necessary for a general control channel is substantially constant, the number of
25 symbols necessary for a specific control channel varies depending on the modulation scheme, the coding rate, the number of antennas, and so on. For example, assuming that the number of necessary symbols is N when the channel coding rate is $1/2$ and the number of antennas is
30 1, the number of necessary symbols becomes $4N$ when the channel coding rate is $1/4$ and the number of antennas is 2. With this embodiment, it is possible to transmit a control channel using a simple fixed format as shown in

FIGs. 7A and 7B even if the number of symbols necessary for the control channel changes. Although the number of symbols necessary for a specific control channel changes, the number of symbols necessary for a general control channel basically does not change. Therefore, it is possible to flexibly cope with the variation in the number of symbols by changing the proportion of the specific control channel to the shared data channel in a given resource block.

10

<FIFTH EMBODIMENT>

For transmission of downlink ACK/NACK described in the first embodiment, particularly for transmission of ACK/NACK for retransmission packets, any one of the following methods may be used: method 1 where radio resources different from those used for initial transmission are reserved for retransmission; method 2 where use of resources having the same uplink grant numbers as those of resources used for initial transmission of packets is prevented; and method 3 where even resources for retransmission are allocated by a grant.

20

Below, methods 1 through 3 are described in detail.

25

(Method 1)

Radio resources different from those used for initial transmission are reserved for retransmission. The radio resources may include codes and/or frequencies. For acknowledgement information for initial transmission, radio resources the number of which is the same as the maximum number of scheduled users are reserved. Meanwhile, for retransmission, radio resources that are different from those used for initial transmission and

30

the number of which is the same as the maximum number of scheduled users are reserved. For example, as shown in FIG. 15, four radio resources #1-#4 are reserved for initial transmission and four radio resources #5-#8 are reserved for retransmission. When the number of actually scheduled users is less than the maximum number of scheduled users, radio resources corresponding to the number of actually scheduled users are used out of the reserved radio resources. For example, in FIG. 15, when only three users are scheduled for initial transmission, radio resource #4 in the reserved radio resources is not used. Similarly, when only two users are scheduled for retransmission, radio resources #7 and #8 in the reserved radio resources are not used.

(Method 2)

Use of resources having the same uplink grant numbers as those of resources used for initial transmission of packets is prevented. For uplink, Sync ARQ is employed so that the difference between the initial transmission timing and the retransmission timing is kept constant. Therefore, it is not necessary to send a grant for retransmission. However, if resources having the same uplink grant numbers as those of resources where errors have occurred are allocated to packets after round trip time (RTT), ACK/NACK collides with the packets. In this method, to prevent such collision, resources having the same uplink grant numbers as those of resources where errors have occurred are not allocated to packets. In other words, no packet is transmitted with the resources having the uplink grant numbers. Here, round trip time (RTT) indicates time required for a communication packet to travel from a sending end to a receiving end and to return to the

sending end. Method 2 makes it possible to use transmission power of the resources not allocated to packets (non-allocated resources) for other resources. Although the transmission efficiency is reduced because
5 no data are transmitted with the non-allocated resources, its effect is small because the frequency of retransmission is very low. In FIG. 16, resources with uplink grant numbers #1-#6 are allocated at time T and if errors are detected in the resources with uplink
10 grant numbers #3 and #6, the resources with uplink grant numbers #3 and #6 are not allocated, i.e., no packet is transmitted with the resources with uplink grant numbers #3 and #6.

(Method 3)

15 In Sync ARQ, retransmission is performed after a predetermined period of time from when previous transmission is performed and the same resources (physical resources, modulation, and coding) used for the previous transmission are used for the
20 retransmission. With Sync ARQ, fragmentation of resources may occur as shown in FIG. 17. In FIG. 17, resources are allocated to three users. The same TTI is allocated to the three users and retransmission is necessary only for user UE2. In a system where a single
25 carrier scheme is employed for uplink, only consecutive subcarriers can be allocated to a user. Therefore, when retransmission is necessary for user UE2, only the previously allocated resources can be allocated to users UE1 and UE3 at the retransmission timing. In other words,
30 it may not be possible to allocate necessary resources to users other than user UE2 and resource use efficiency may be reduced. To prevent fragmentation of resources, it is proposed to allocate resources by a grant even in

a retransmission process (see, for example, 3GPP R2-070060). Allocating resources for retransmission by a grant eliminates the need to reserve resources for ACK/NACK for retransmission packets.

5 Only a part of information items may be included in a grant to be used for allocation of resources for retransmission. That is, a grant including all normal information items as shown in FIG. 18 may be used (a), or a grant including only a part of the
10 information items shown in FIG. 18 may be used (b).

FIG. 18 shows a configuration of a grant. The control signaling information of the grant includes uplink RB allocation information, a UE ID, transport format information, transmission power, and a
15 demodulation reference signal format. For a grant used in a retransmission process, uplink RB assignment information and a UE ID are necessary.

Although the present invention is described above in different embodiments, the distinctions between
20 the embodiments are not essential for the present invention, and the embodiments may be used individually or in combination. Although specific values are used in the above descriptions to facilitate the understanding of the present invention, the values are just examples
25 and different values may also be used unless otherwise mentioned.

The present invention is not limited to the specifically disclosed embodiments, and variations and modifications may be made without departing from the
30 scope of the present invention. Although functional block diagrams are used to describe apparatuses in the above embodiments, the apparatuses may be implemented by hardware, software, or a combination of them.

The present international application claims priority from Japanese Patent Application No. 2007-073733 filed on March 20, 2007, the entire contents of which are hereby incorporated herein by reference.

CLAIMS

1. A base station employing a multicarrier
scheme and performing frequency scheduling in a
5 frequency band including multiple resource blocks each
including one or more subcarriers, the base station
comprising:

a frequency scheduler configured to receive
channel condition information from communication
10 terminals and to generate scheduling information for
allocating one or more of the resource blocks to each of
selected ones of the communication terminals having good
channel conditions based on the channel condition
information;

15 a coding and modulation unit configured to
encode and modulate control channels including a general
control channel to be decoded by the communication
terminals in general and specific control channels to be
decoded by the selected ones of the communication
20 terminals that are allocated one or more of the resource
blocks; and

a multiplexing unit configured to time-
division-multiplex the general control channel and the
specific control channels according to the scheduling
25 information,

wherein the resource blocks specified in the
specific control channels and allocated for uplink data
transmission are associated with the resource blocks
used to transmit downlink acknowledgement information.

30

2. The base station as claimed in claim 1,
wherein
the general control channel is mapped to

resources distributed across the frequency band; and
the specific control channels for the selected
ones of the communication terminals are mapped to
resources within the corresponding resource blocks
5 allocated to the selected ones of the communication
terminals.

3. The base station as claimed in claim 1,
wherein a downlink pilot channel is also mapped to
10 resources distributed across the frequency band.

4. The base station as claimed in claim 1,
wherein the general control channel and the specific
control channels are error-correction-coded separately.
15

5. The base station as claimed in claim 1,
wherein the general control channel includes one or more
of identification information of the communication
terminals, resource block allocation information, and
20 numbers of antennas used for communications.

6. The base station as claimed in claim 1,
wherein each of the specific control channels includes
one or more of information indicating a modulation
25 scheme of a data channel, information indicating a
coding scheme of the data channel, and automatic repeat
request information.

7. The base station as claimed in claim 1,
30 wherein
transmission power control is performed for
the general control channel; and
one or both of transmission power control and

adaptive modulation and coding are performed for the specific control channels.

8. The base station as claimed in claim 7,
5 wherein transmission power control is performed for the general control channel such that the selected ones of the communication terminals are able to receive the general control channel with high quality.

10 9. The base station as claimed in claim 7, wherein the general control channel includes modulation schemes and/or coding schemes applied to the respective specific control channels.

15 10. The base station as claimed in claim 9, wherein when both transmission power control and adaptive modulation and coding are performed for the specific control channels, a total number of combinations of modulation schemes and coding schemes
20 for the specific control channels is less than a total number of combinations of modulation schemes and coding schemes for a shared data channel.

11. The base station as claimed in claim 1,
25 wherein

the general control channel includes a paging indicator, resource allocation information for downlink data channels, and information indicating a number of streams to be transmitted from one or more antennas of
30 the base station; and

each of the specific control channels includes information indicating weighting factors used for precoding of the one or more antennas of the base

station, a transport format for a corresponding one of the downlink data channels, and retransmission control information.

5 12. The base station as claimed in claim 7, wherein the specific control channels or the general control channel includes uplink data transmission information including acknowledgement information for uplink data channels, resource allocation information
10 for the uplink data channels, transmission power information of the communication terminals, and timing control information for synchronizing the communication terminals.

15 13. The base station as claimed in claim 12, wherein symbol positions of the uplink data transmission information in a downlink control channel is uniquely identifiable based on broadcast information.

20 14. The base station as claimed in claim 13, wherein a transport format of the downlink control channel is variable.

 15. The base station as claimed in claim 7,
25 wherein a broadcast channel transmitted from the base station includes a transport format of a downlink control channel, a maximum number of multiplexed users, and information indicating arrangement of resource blocks.

30 16. The base station as claimed in claim 15, wherein symbol positions of resource allocation information for downlink data channels in the downlink

control channel are uniquely identifiable based on broadcast information.

17. The base station as claimed in claim 7,
5 wherein an L3 signaling control information to be transmitted from the base station to the selected ones of the communication terminals includes information indicating whether localized FDM or distributed FDM is used and information indicating a transport format used
10 in persistent scheduling.

18. The base station as claimed in claim 7, wherein sets of control information for the respective communication terminals in the general control channel
15 are channel-coded separately.

19. The base station as claimed in claim 7, wherein downlink transmission power for all multiplexed users is kept substantially constant.
20

20. The base station as claimed in claim 1, wherein resource blocks other than the resource blocks allocated for uplink data transmission are allocated for retransmission.
25

21. The base station as claimed in claim 1, wherein if an error is detected in a packet transmitted using one of the resource blocks allocated for uplink data transmission, use of the one of the resource blocks
30 for transmission is prevented.

22. The base station as claimed in claim 1, wherein

if errors are detected in packets transmitted using the resource blocks allocated for uplink data transmission, a grant is used to allocate resource blocks for retransmission; and

5 the grant includes only a part of normal grant information.

23. A transmission method used by a base station that employs a multicarrier scheme and performs
10 frequency scheduling, the method comprising the steps of:

receiving channel condition information from communication terminals and generating scheduling information for allocating one or more of resource
15 blocks each including one or more subcarriers to each of selected ones of the communication terminals having good channel conditions based on the channel condition information;

encoding and modulating control channels
20 including a general control channel to be decoded by the communication terminals in general and specific control channels to be decoded by the selected ones of the communication terminals that are allocated one or more of the resource blocks; and

25 time-division-multiplexing the general control channel and the specific control channels according to the scheduling information,

wherein the resource blocks specified in the specific control channels and allocated for uplink data
30 transmission are associated with the resource blocks used to transmit downlink acknowledgement information.

24. A communication terminal used in a

communication system where a multicarrier scheme is employed and frequency scheduling is performed, the communication terminal comprising:

- 5 a receiving unit configured to receive control channels including a general control channel to be decoded by communication terminals in general and specific control channels to be decoded by selected communication terminals to each of which one or more resource blocks are allocated;
- 10 a separating unit configured to separate the general control channel and the specific control channels that are time-division-multiplexed;
- a control channel decoding unit configured to decode the general control channel and to decode a
15 corresponding one of the specific control channels that is included in the one or more of the resource blocks allocated to the communication terminal based on resource block allocation information in the general control channel; and
- 20 a transmitting unit configured to transmit a data channel using one or more resource blocks specified in the corresponding one of the specific control channels and allocated for uplink data transmission,
wherein the resource blocks specified in the
25 specific control channels and allocated for uplink data transmission are associated with resource blocks used to transmit downlink acknowledgement information.

25. A reception method used by a communication
30 terminal in a communication system where a multicarrier scheme is employed and frequency scheduling is performed, the method comprising the steps of:

receiving control channels including a general

control channel to be decoded by communication terminals in general and specific control channels to be decoded by selected communication terminals to each of which one or more resource blocks are allocated;

5 separating the general control channel and the specific control channels that are time-division-multiplexed;

 decoding the general control channel and decoding a corresponding one of the specific control
10 channels that is included in the one or more of the resource blocks allocated to the communication terminal based on resource block allocation information in the general control channel; and

 transmitting a data channel using one or more
15 resource blocks specified in the corresponding one of the specific control channels and allocated for uplink data transmission,

 wherein the resource blocks specified in the specific control channels and allocated for uplink data
20 transmission are associated with resource blocks used to transmit downlink acknowledgement information.