

DESCRIPTION

Title of Invention

APPARATUSES, METHODS, AND INTEGRATED CIRCUITS FOR
TRANSMITTING AND RECEIVING REFERENCE SIGNALS

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Technical Field

[0001] The present invention relates to a radio transmission apparatus and a reference signal transmission method.

10 Background Art

[0002] For an uplink channel of LTE-Advanced, which is an evolved version of 3rd generation partnership project long-term evolution (3GPP LTE), using both contiguous frequency transmission and non-contiguous frequency transmission is under
15 consideration (see Non-Patent Literature 1). That is, in communication from each radio communication terminal apparatus (hereinafter referred to as "terminal") to a radio communication base station apparatus (hereinafter referred to as "base station"), contiguous frequency transmission and non-contiguous frequency
20 transmission are switched.

[0003] Contiguous frequency transmission is a method of transmitting a data signal and a reference signal (RS) by allocating such signals to contiguous frequency bands. For example, as shown in FIG.1, in contiguous frequency
25 transmission, a data signal and a reference signal are allocated to contiguous transmission bands. In contiguous frequency transmission, a base station allocates contiguous frequency bands

to each terminal based on the reception quality per frequency band for each terminal, so that it is possible to obtain frequency scheduling effects.

[0004] On the other hand, non-contiguous frequency
5 transmission is a method of transmitting a data signal and a reference signal by allocating such signals to non-contiguous frequency bands, which are dispersed in a wide range of band. For example, as shown in FIG.2, in non-contiguous frequency transmission, it is possible to allocate a data signal and a
10 reference signal to transmission bands which are dispersed all over the frequency band. In non-contiguous frequency transmission, compared to contiguous frequency transmission, the flexibility of assignment of a data signal and a reference signal to frequency bands is improved, so that it is possible to gain greater
15 frequency scheduling effects. Further, in non-contiguous frequency transmission, it is possible to decrease the probability that all of a data signal or a reference signal of a terminal will get in a valley in fading. That is, according to non-contiguous transmission, it is possible to obtain frequency diversity effects
20 and suppress deterioration of reception characteristics.

[0005] Further, in LTE, as shown in FIG's.1 and 2, a terminal transmits a data signal and a reference signal in the same transmission band (see Non-Patent Literature 2). Then, a base station estimates a channel estimation value of the transmission
25 band to which a data signal of each terminal is allocated, using a reference signal, and demodulates the data signal using the channel estimation value.

[0006] Further, in LTE, as a reference signal to use for propagation path estimation of an uplink channel, an orthogonal code called a cyclic shift sequence, which has high interference suppression effects, is employed (see Non-Patent Literature 3).

5 Because one code sequence (ZC sequence) allocated to each base station (cell) is cyclically shifted by a different amount of cyclic shift, it is possible to obtain a plurality of cyclic shift sequences which are orthogonal to each other. An amount of shifting between cyclic shift sequences is set greater than delay time in a
10 multipath channel. As shown in FIG.3, a terminal transmits a cyclic shift sequence generated using a different amount of cyclic shift per terminal or antenna. A base station obtains a correlation value corresponding to each cyclic shift sequence by receiving a plurality of cyclic shift sequences that are
15 multiplexed in a channel and performing a correlation calculation on a received signal and a base code sequence. That is, as shown in FIG.4, the correlation value corresponding to cyclic shift sequence (CS #2) appears at the position which is shifted by cyclic shift width Δ from the position at which the correlation value corresponding to cyclic shift sequence (CS #1) appears.
20 By setting cyclic shift width Δ greater than delay time in a multipath channel, it is possible to extract a correlation value in the period (detection window) in which an incoming wave of the desired wave exists.

25 [0007] Here, as a method of transmitting a reference signal in non-contiguous frequency transmission, two methods are possible. First, in transmission method (a) in FIG.5, reference signals are

generated from one code sequence. That is, transmission is performed by dividing one code sequence by a width corresponding to the bandwidth of each contiguous frequency band (hereinafter referred to as "cluster"), and allocating the
5 obtained subsequence to each cluster.

[0008] On the other hand, in transmission method (b) in FIG.6, reference signals are generated from a plurality of code sequences. That is, transmission is performed by generating a plurality of code sequences corresponding to the bandwidth of
10 each cluster, and allocating each code sequence to clusters.

Citation List

Non-Patent Literature

[0009]

15 NPL 1

R1-090257, Panasonic, "System performance of uplink non-contiguous resource allocation"

NPL 2

3GPP TS 36.212 V8.3.0, "E-UTRA Multiplexing and channel
20 coding (Release 8)," 2008-05

NPL 3

3GPP TS 36.211 V8.3.0, "Physical Channels and Modulation (Release 8)," 2008-05

25 Summary of Invention

Technical Problem

[0010] However, the above-described method of transmitting a

reference signal in non-contiguous frequency transmission has the following problem.

[0011] In transmission method (a), compared to transmission method (b), a coding sequence (a correlation length) can be made longer. That is, transmission method (a) has an advantage of reducing interference. Specifically, in the case where a ZC sequence is used as a code sequence, when a sequence length is N , the cross-correlation value between ZC sequences will be constant at $1/\sqrt{N}$. When sequence length N doubles, the cross-correlation value will be $1/\sqrt{2}$ times, making it possible to suppress inter-cell interference power value lower by 3dB.

[0012] However, transmission method (a) has a problem that accuracy of channel estimation deteriorates when the number of clusters is large or channel variation in the frequency band between clusters is significant. As shown in FIG.7, when transmission method (a) is adopted, a base station obtains a correlation value (that is, a delay profile) by performing complex division on a received reference signal that is obtained by connecting a reference signal received as a plurality of clusters back to one code sequence, and a reference signal replica, in the frequency domain, and by performing IDFT processing on the result of division to convert into the time domain. At the point where reference signals are connected, channel variation becomes noncontinuous, and interference occurs resulting from this noncontinuity. This interference increases as the number of clusters is greater, because the number of noncontinuous points increases as the number of clusters is greater. Further, when the

number of clusters is greater, a bandwidth per cluster becomes narrower and a correlation length becomes smaller, decreasing interference suppression effects and further increasing interference effects. As described above, when interference
5 increases, the accuracy of detecting a desired wave deteriorates and separation of a plurality of cyclic shift sequences becomes difficult, drastically deteriorating the accuracy of channel estimation as well.

[0013] On the other hand, transmission method (b) has an
10 advantage that deterioration of the accuracy of channel estimation can be prevented even when channel variation between clusters is significant. As shown in FIG.8, when transmission method (b) is adopted, a base station obtains a correlation value (delay profile) by performing complex division on a received reference signal of
15 each cluster and a reference signal replica, in the frequency domain, and by performing IDFT processing on the result of division to convert into the time domain. In transmission method (b), because there is no noncontinuous point of channel variation as is in transmission method (a), it is possible to prevent
20 interference from occurring.

[0014] However, transmission method (b) has a problem that, because a sequence length per cluster (a correlation length) is shorter, compared with transmission method (a), interference suppression effects decrease and the accuracy of channel
25 estimation deteriorates. For example, when the number of clusters is 2 and the bandwidths of the two clusters are equal, the interference level in transmission method (b) increases 3dB

greater than the interference level in transmission method (a).

[0015] It is therefore an object of the present invention to provide a radio transmission apparatus and a reference signal transmission method for improving the accuracy of channel
5 estimation.

Solution to Problem

[0016] One aspect of a radio transmission apparatus according to the present invention employs a configuration to have a radio
10 transmission apparatus that transmits a reference signal using n (n is a natural number of 2 or greater) bandwidth blocks that are positioned at intervals from each other in a direction of frequency, the apparatus comprising: a formation section that forms the reference signal based on one of a first formation
15 method, in which n subsequences are formed as the reference signal by dividing one base code sequence into a length to match each bandwidth block, and a second formation method, in which n code sequences are formed as the reference signal by adjusting lengths of n base code sequences to match each bandwidth block;
20 and a switch section that switches reference signal formation methods in the formation section between the first formation method and the second formation method based on a switch threshold value and the number of the bandwidth blocks n .

[0017] One aspect of a reference signal transmission method
25 according to the present invention employs a configuration to have a reference signal transmission method of transmitting a reference signal using n (n is a natural number of 2 or greater)

bandwidth blocks that are positioned at intervals from each other in a direction of frequency, the method comprising steps of: forming the reference signal based on one of a first formation method, in which n subsequences are formed as the reference
5 signal by dividing one base code sequence into a length to match each bandwidth block, and a second formation method, in which n code sequences are formed as the reference signal by adjusting lengths of n base code sequences to match each bandwidth block; and switching reference signal formation methods in a formation
10 section between the first formation method and the second formation method based on a switch threshold value and the number of the bandwidth blocks n .

Advantageous Effects of Invention

15 [0018] According to the present invention, it is possible to provide a radio transmission apparatus and a reference signal transmission method for improving the accuracy of channel estimation.

20 Brief Description of Drawings

[0019]

FIG.1 shows contiguous frequency transmission;

FIG.2 shows non-contiguous frequency transmission;

FIG.3 shows cyclic shift sequences;

25 FIG.4 shows correlation values corresponding to cyclic shift sequences;

FIG.5 shows reference signal transmission method (a) in

non-contiguous frequency transmission;

FIG.6 shows reference signal transmission method (b) in non-contiguous frequency transmission;

FIG.7 shows a problem in reference signal transmission
5 method (a);

FIG.8 shows a problem in reference signal transmission method (b);

FIG.9 is a block diagram showing a configuration of a terminal according to Embodiment 1 of the present invention;

10 FIG.10 is a block diagram showing a configuration of a base station according to Embodiment 1 of the present invention;

FIG.11 is a block diagram showing a configuration of the channel estimation section in FIG.10;

FIG.12 shows a relationship between the first reference
15 signal formation method and the second reference signal formation method according to Embodiment 1;

FIG.13 shows switch control between the first reference signal formation method and the second reference signal formation method according to Embodiment 1;

20 FIG.14 shows adjustment of threshold values used to switch reference signal formation methods;

FIG.15 shows switch control between the first reference signal formation method and the second reference signal formation method according to Embodiment 1;

25 FIG.16 shows an embodiment when applied to LTE-Advanced;

FIG.17 shows a relationship between the first reference

signal formation method and the second reference signal formation method according to Embodiment 2;

FIG.18 shows switch control between the first reference signal formation method and the second reference signal formation method according to Embodiment 2; and

FIG.19 shows adjustment of threshold values used to switch reference signal formation methods.

Description of Embodiments

[0020] Now, embodiments of the present invention will be described in detail with reference to the accompanying drawings.

[0021] (Embodiment 1)

[Configuration of Terminal]

FIG.9 is a block diagram showing a configuration of terminal 100 according to Embodiment 1 of the present invention. In FIG.9, terminal 100 is provided with RF reception section 101, demodulation section 102, decoding section 103, resource assignment information setting section 104, threshold value setting section 105, reference signal control section 106, reference signal generation section 107, encoding section 108, modulation section 109, fast Fourier transform (FFT) section 110, mapping section 111, inverse fast Fourier transform (IFFT) section 112, and RF transmission section 113.

[0022] RF reception section 101 performs reception processing such as down-conversion and A/D conversion on a signal received via an antenna, and outputs the signal on which reception processing is performed to demodulation section 102.

[0023] Demodulation section 102 performs equalization processing and demodulation processing on the signal received from RF reception section 101, and outputs the processed signal to decoding section 103.

5 [0024] Decoding section 103 performs decoding processing on the signal received from demodulation section 102 and extracts reception data and control information.

[0025] Encoding section 108 encodes transmission data and outputs the obtained encoded data to modulation section 109.

10 [0026] Modulation section 109 modulates the encoded data received from encoding section 108 and outputs the modulated signal to FFT section 110.

[0027] FFT section 110 performs FFT processing on the modulated signal received from modulation section 109 and
15 outputs the obtained signal to mapping section 111.

[0028] Mapping section 111 maps a data signal received from FFT section 110 and a reference signal received from reference signal generation section 107 to a frequency domain resource according to a frequency assignment information received from
20 resource assignment information setting section 104, and outputs the obtained signal to IFFT section 112.

[0029] Threshold value setting section 105 adjusts a switch threshold value in reference signal control section 106. Threshold value setting section 105 receives information about
25 clusters from resource assignment information setting section 104 and adjusts a switch threshold value in reference signal control section 106 based on a frequency interval between clusters.

[0030] Reference signal control section 106 receives information about clusters from resource assignment information setting section 104, compares which one of the number of clusters and the switch threshold value is smaller or greater, and, based on
5 the result of the comparison, determines a method of forming a reference signal in reference signal generation section 107. Reference signal control section 106 switches reference signal formation methods in reference signal generation section 107 by outputting identification information of the determined reference
10 signal formation method to reference signal generation section 107.

[0031] Resource assignment information setting section 104 outputs frequency assignment information about a reference signal and a data signal, including the number of clusters, a frequency
15 position and a bandwidth of each cluster, to threshold value setting section 105, reference signal control section 106, and mapping section 111. Contents of resource assignment information are reported from base station 200 (described later) to terminal 100, and are input to resource assignment information
20 setting section 104 via RF reception section 101, demodulation section 102, and decoding section 103.

[0032] Reference signal generation section 107 generates a reference signal based on a reference signal formation method indicated by identification information received from reference
25 signal control section 106, and outputs the reference signal to mapping section 111. As methods of forming a reference signal, as described above, there are a first formation method

(transmission method (a)), in which subsequences corresponding to the number of clusters are formed as a reference signal by dividing one base code sequence into the length to match each cluster, and a second formation method (transmission method (b)),
5 in which base code sequences corresponding to the number of clusters are formed as a reference signal by adjusting lengths of base code sequences corresponding to the number of clusters to match each cluster.

[0033] IFFT section 112 performs IFFT processing on the signal
10 received from mapping section 111 and outputs the obtained signal to RF transmission section 113.

[0034] RF transmission section 113 performs transmission processing such as D/A conversion, up-conversion, and amplification on the signal received from IFFT section 112, and
15 transmits the obtained signal by air to base station 200 via an antenna.

[0035] [Configuration of Base Station]

FIG.10 is a block diagram showing a configuration of base station 200 according to Embodiment 1 of the present invention.
20 In FIG.10, base station 200 is provided with RF reception section 201, discrete Fourier transform (DFT) section 202, demapping section 203, resource assignment information setting section 204, threshold value setting section 205, channel estimation control section 206, channel estimation section 207, frequency domain
25 equalization section 208, IFFT section 209, demodulation section 210, and decoding section 211.

[0036] RF reception section 201 performs reception processing

such as down-conversion and A/D conversion on a signal received via an antenna, and outputs the obtained signal to DFT section 202.

[0037] DFT section 202 performs DFT processing on the signal received from RF reception section 201 to convert a time domain signal into a frequency domain signal. Then, DFT section 202 outputs the frequency domain signal to demapping section 203.

[0038] Demapping section 203 extracts a data signal and a reference signal from the frequency domain signal received from DFT section 202 according to the frequency assignment information received from resource assignment information setting section 204. Then, demapping section 203 outputs the extracted data signal to frequency domain equalization section 208 and outputs the reference signal to channel estimation section 207.

[0039] Resource assignment information setting section 204 outputs a frequency assignment information that is allocated to terminal 100, including the number of clusters, a frequency position and a bandwidth of each cluster, to threshold value setting section 205, channel estimation control section 206, and demapping section 203. In this regard, contents of resource assignment information are reported from base station 200 to terminal 100 in advance.

[0040] Threshold value setting section 205 adjusts a switch threshold value in channel estimation control section 206. Threshold value setting section 205 receives information about clusters from resource assignment information setting section

204, and adjusts the switch threshold value in channel estimation control section 206 based on the frequency interval between clusters.

[0041] Channel estimation control section 206 switches a
5 channel estimation method in channel estimation section 207 to a channel estimation method corresponding to the reference signal transmission method in terminal 100. That is, channel estimation control section 206 receives information about clusters from resource assignment information setting section 204, compares
10 which one of the number of clusters and a switch threshold value is smaller or greater, and, based on the result of the comparison, determines a channel estimation method in channel estimation section 207. Channel estimation control section 206 switches channel estimation methods in channel estimation section 207 by
15 outputting identification information of the determined channel estimation method to channel estimation section 207.

[0042] Channel estimation section 207 performs channel estimation using the channel estimation method indicated by identification information received from channel estimation
20 control section 206, and outputs the result of channel estimation to frequency domain equalization section 208. A configuration of channel estimation section 207 will be described in detail later.

[0043] Frequency domain equalization section 208 performs
25 equalization processing on the data signal received from demapping section 203 using the channel estimation result (i.e. a channel frequency response) received from channel estimation

section 207. Then, frequency domain equalization section 208 outputs the result of equalization processing to IFFT section 209.

[0044] IFFT section 209 performs IFFT processing on the data signal received from frequency domain equalization section 208 and outputs the obtained signal to demodulation section 210.

[0045] Demodulation section 210 performs demodulation processing on the signal received from IFFT section 209 and outputs the obtained signal to decoding section 211.

[0046] Decoding section 211 performs decoding processing on the signal received from demodulation section 210, and outputs the obtained reception data.

[0047] FIG.11 is a block diagram showing a configuration of channel estimation section 207. In FIG.11, channel estimation section 207 is provided with switching switch 220, estimation processing section 230, and estimation processing section 240.

[0048] Switching switch 220 redirects the output of the reference signal received from demapping section 203 to estimation processing section 230 or estimation processing section 240 based on identification information received from channel estimation control section 206.

[0049] Estimation processing section 230 performs a first channel estimation method corresponding to the first reference signal formation method. Estimation processing section 230 is provided with cluster combination section 231, division section 232, IFFT section 233, mask processing section 234, and DFT section 235.

[0050] Cluster combination section 231 connects, in a frequency

domain, a plurality of clusters used to transmit a reference signal in terminal 100, and outputs the received reference signal thus obtained to division section 232.

[0051] Division section 232 performs complex division on the received reference signal received from cluster combination section 231 using the reference signal replica (i.e. the reference signal transmitted from terminal 100). Then, division section 232 outputs the result of division (i.e. a correlation value) to IFFT section 233.

[0052] IFFT section 233 performs IFFT processing on the signal received from division section 232, and outputs the obtained signal to mask processing section 234.

[0053] Mask processing section 234, as an extraction means of a requested desired wave, extracts a correlation value at a period (a detection window) in which a correlation value of the desired cyclic shift sequence by performing mask processing on the signal received from IFFT section 233, which is equivalent to a delay profile, based on an amount of cyclic shift used in terminal 100. Then, mask processing section 234 outputs the extracted correlation value to DFT section 235.

[0054] DFT section 235 performs DFT processing on the correlation value input from mask processing section 234 and outputs the obtained signal to frequency domain equalization section 208. This signal output from DFT section 235 is a channel estimation value in which channel variation (i.e. a channel frequency response) is estimated.

[0055] Estimation processing section 240 performs a second

channel estimation method corresponding to the second reference signal formation method. Estimation processing section 240 is provided with cluster extraction section 241 and estimation value calculation sections 242-1 to n which correspond to each cluster.

5 Estimation value calculation section 242 is provided with division section 243, IFFT section 244, mask processing section 245, and DFT section 246.

[0056] Cluster extraction section 241 outputs each of the number of clusters n used to transmit a reference signal in terminal 100 to estimation value calculation sections 242-1 to n. Estimation value calculation section 242 performs the same processing as performed in division section 232, IFFT section 233, mask processing section 234, and DFT section 235.

[0057] [Operation of Terminal]

15 Terminal 100 having the above configuration will be described below.

[0058] As described above, in terminal 100, reference signal control section 106 switches reference signal formation methods by controlling reference signal generation section 107.

20 [0059] The above-described first reference signal formation method (transmission method (a)) and second reference signal formation method (transmission method (b)) have the relationship shown in FIG.12. That is, the accuracy of channel estimation is constant regardless of the number of clusters when the second reference signal formation method is used. On the other hand, the accuracy of channel estimation tends to lower as the number of clusters increases when the first reference signal formation

25

method is used. Therefore, with a certain number of clusters N being a threshold, the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation of the second reference signal formation method are reversed. That is, when the number of clusters is N or smaller, the channel estimation value of the first reference signal formation method exceeds the channel estimation value of the second reference signal formation method, while, inversely, when the number of clusters is greater than N , the channel estimation value of the second reference signal formation method exceeds the channel estimation value of the first reference signal formation method.

[0060] Therefore, by using the number of clusters of a point at which the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation of the second reference signal formation method are reversed as a switch threshold value, it is possible to select a more advantageous reference signal formation method with respect to the accuracy of channel estimation according to the number of clusters. By performing this kind of switch control of reference signal formation methods, base station 200 can obtain the accuracy of channel estimation shown with the solid line in FIG.13.

[0061] Further, as shown in FIG.14, the accuracy of channel estimation of the first reference signal formation method depends on the frequency interval between clusters. That is, the accuracy curve of channel estimation shifts upward as the frequency

interval between clusters is narrower. Therefore, when the frequency interval between clusters changes, the point at which the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation of the second reference signal formation method are reversed also shifts.

[0062] Therefore, because threshold value setting section 105 adjusts a switch threshold value in reference signal control section 106 based on the frequency interval between clusters, it is possible to accurately select a reference signal formation method.

[0063] The above-described switch control of a transmission method in terminal 100 is summarized in FIG.15. That is, when the frequency interval is Y or greater, $N1$ is used as a switch threshold value, and transmission method (a) and transmission method (b) are switched based on which one of this threshold value and the number of clusters is smaller or greater. On the other hand, when the frequency interval is smaller than Y , $N2$ is used as a switch threshold value.

[0064] As described above, according to the present embodiment, in terminal 100 that transmits a reference signal using n (n is a natural number of 2 or greater) band blocks (here, equivalent to clusters) which are positioned at intervals from each other in a direction of frequency, reference signal control section 106 switches the reference signal formation methods in reference signal generation section 107 between the first formation method and the second formation method, based on the number of band blocks n .

[0065] By this means, it is possible to select a more

advantageous reference signal formation method with respect to the accuracy of channel estimation, and, as a result of this, it is possible to improve the accuracy of channel estimation.

[0066] Further, in terminal 100, threshold value setting section 5 105 adjusts the switch threshold value based on the frequency interval between band blocks.

[0067] By this means, it is possible to accurately select a reference signal formation method, and, as a result of this, it is possible to further improve the accuracy of channel estimation.

10 [0068] Further, a case has been described with the above description where each cluster is treated as a band block. However, the present invention is by no means limited to this, and it is equally possible to use a band block formed with a plurality of clusters as an equivalent of the cluster described in
15 Embodiment 1. That is, when there are a plurality of band blocks formed with a plurality of clusters, it is possible to employ a first formation method in which subsequences corresponding to the number of band blocks are formed as a reference signal by dividing one base code sequence into the length to match each
20 band block, and a second formation method in which code sequences corresponding to the number of band blocks are formed as a reference signal by adjusting the lengths of base code sequences corresponding to the number of band blocks to match each band block.

25 [0069] For example, a component carrier, which is a predetermined system bandwidth in LTE-Advanced, is equivalent to this band block. For a component carrier, a maximum value of

the number of clusters that can be contained is defined by, for example, restricting the signaling format. Therefore, in such a case, it is possible to switch reference signal transmission methods according to the number of component carriers. For
5 example, in the case where the maximum value of the number of clusters in component carrier is 2, as shown in FIG.16, it is possible to obtain the same effects as in above Embodiment 1 even by selecting transmission method (a) when the number of component carriers is 1, while selecting transmission method (b)
10 when the number of component carriers is 2 or greater.

[0070] (Embodiment 2)

A case will be described here with Embodiment 2 where reference signal formation methods are switched based on a "cluster bandwidth." That is, reference signal formation methods
15 are switched based on a total bandwidth of n clusters in addition to a switch threshold value and the number of clusters n . Further, basic configurations of a terminal and a base station according to the present embodiment are the same as the configurations of the terminal and the base station explained in
20 Embodiment 1. Therefore, the terminal and the base station according to the present Embodiment will also be explained using FIG's.9 and 10.

[0071] [Configuration of Terminal]

Reference signal control section 106 in terminal 100
25 according to Embodiment 2 receives information about clusters from resource assignment information setting section 104, and first calculates a "cluster bandwidth." This "cluster bandwidth"

means an average bandwidth per cluster and can be obtained by dividing a total bandwidth of n clusters by the number of clusters n.

[0072] Then, reference signal control section 106 compares which one of the cluster bandwidth and a switch threshold value is smaller or greater, and, based on the result of the comparison, determines a reference signal formation method in reference signal generation section 107. Reference signal control section 106 switches reference signal formation methods in reference signal generation section 107 by outputting identification information of the determined reference signal formation method to reference signal generation section 107.

[0073] [Configuration of Base Station]

Further, channel estimation control section 206 in base station 200 according to Embodiment 2 switches the channel estimation method in channel estimation section 207 to the channel estimation method corresponding to the reference signal transmission method in terminal 100. That is, channel estimation control section 206 receives information about clusters from resource assignment information setting section 204, and first calculates a "cluster bandwidth," as is the case with reference signal control section 106.

[0074] Then, channel estimation control section 206 compares which one of the cluster bandwidth and a switch threshold value is smaller or greater, and, based on the result of the comparison, determines a reference signal formation method in reference signal generation section 107. Channel estimation control

section 206 switches channel estimation methods in channel estimation section 207 by outputting identification information of the determined channel estimation method to channel estimation section 207.

5 [0075] [Operation of Terminal]

As described above, in terminal 100, reference signal control section 106 switches reference signal formation methods by controlling reference signal generation section 107.

[0076] The above-described first reference signal formation method (transmission method (a)) and second reference signal formation method (transmission method (b)) have a relationship shown in FIG.17, when the horizontal axis of the graph shows a cluster bandwidth.

[0077] Especially, as shown in FIG.17, the performance of transmission method (a) depends on the cluster bandwidth and deteriorates as the cluster bandwidth is narrower. When the cluster bandwidth is narrower, the number of clusters tends to increase. Therefore, when the number of non-continuous points in channel variation in calculating channel estimation increases, interference increases. Further, the performance of transmission method (b) also depends on the cluster bandwidth and deteriorates as the cluster bandwidth is narrower. Because the correlation length becomes smaller according to the cluster bandwidth, the interference suppression effects are lowered. This performance deterioration in transmission method (b) is greater than the performance deterioration in transmission method (a).

[0078] On the other hand, the performance in transmission

method (b) is greater than the performance in transmission method (a) when the cluster bandwidth is wider. In transmission method (b), when the cluster bandwidth is greater, sufficient interference suppression effects can be obtained and interference can be suppressed to a noise level. Further, while, in transmission method (b), the performance does not deteriorate even the number of clusters is large, in transmission method (a), great interference due to non-continuous of channel variation occurs even when the cluster bandwidth is wide.

[0079] That is, here again, with a certain cluster bandwidth M being a threshold, the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation of the second reference signal formation method are reversed. That is, when the cluster bandwidth is M or narrower, the channel estimation value of the first reference signal formation method exceeds the channel estimation value of the second reference signal formation method, while, inversely, when the cluster bandwidth is wider than M , the channel estimation value of the second reference signal formation method exceeds the channel estimation value of the first reference signal formation method.

[0080] Therefore, by using a cluster bandwidth of the point at which the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation of the second reference signal formation method are reversed as a switch threshold value, it is possible to select a more advantageous reference signal formation method with respect to

the accuracy of channel estimation according to the cluster bandwidth. By performing this kind of switch control of reference signal formation methods, base station 200 can obtain the accuracy of channel estimation shown with the solid line in
5 FIG.18.

[0081] Further, as shown in FIG.19, the accuracy of channel estimation of the first reference signal formation method depends on the frequency interval between clusters even when the horizontal axis of the graph shows a cluster bandwidth. That is,
10 the accuracy curve of channel estimation shifts upward as the frequency interval between clusters is narrower. Therefore, when the frequency interval between clusters changes, the point at which the accuracy of channel estimation of the first reference signal formation method and the accuracy of channel estimation
15 of the second reference signal formation method are reversed also shifts.

[0082] Therefore, because threshold value setting section 105 adjusts a switch threshold value in reference signal control section 106 based on the frequency interval between clusters, it is
20 possible to accurately select a reference signal formation method.

[0083] As described above, according to the present embodiment, in terminal 100, reference signal control section 106 switches reference signal formation methods based on the "cluster bandwidth." That is, reference signal formation methods are
25 switched based on a total bandwidth of n clusters in addition to a switch threshold value and the number of clusters n .

[0084] By this means, it is possible select a more advantageous

reference signal formation method with respect to the accuracy of channel estimation, and, as a result of this, it is possible to improve the accuracy of channel estimation.

[0085] Although cases have been described with the above
5 embodiments where reference signal formation methods are switched based on the cluster bandwidth, it is possible to use the narrowest bandwidth out of the bandwidths of n clusters instead of the cluster bandwidth.

[0086] (Other embodiment)

10 Cases have been described with above Embodiment 1 and Embodiment 2 where both of reference signal transmission methods in terminal 100 and channel estimation methods in base station 200 switch according to the number of clusters or a cluster bandwidth. However, it is possible to switch only channel
15 estimation methods in base station 200. That is, it is possible to fix the reference signal transmission method in terminal 100 to transmission method (a) or transmission method (b), and switch channel estimation methods in base station 200 according to the number of clusters or a cluster bandwidth. By this means, it is
20 also possible to obtain effects similar to the effects of Embodiment 1 and Embodiment 2.

[0087] Also, although cases have been described with the above embodiments as examples where the present invention is configured by hardware, the present invention can also be realized
25 by software.

[0088] Each function block employed in the description of each of the aforementioned embodiments may typically be implemented

as an LSI constituted by an integrated circuit. These may be individual chips or partially or totally contained on a single chip. "LSI" is adopted here but this may also be referred to as "IC," "system LSI," "super LSI," or "ultra LSI" depending on differing
5 extents of integration.

[0089] Further, the method of circuit integration is not limited to LSI's, and implementation using dedicated circuitry or general purpose processors is also possible. After LSI manufacture, utilization of a programmable FPGA (Field Programmable Gate
10 Array) or a reconfigurable processor where connections and settings of circuit cells within an LSI can be reconfigured is also possible.

[0090] Further, if integrated circuit technology comes out to replace LSI's as a result of the advancement of semiconductor
15 technology or a derivative other technology, it is naturally also possible to carry out function block integration using this technology. Application of biotechnology is also possible.

[0091] The disclosure of Japanese Patent Application No. 2009-018632, filed on January 29, 2009, including the specification,
20 drawings and abstract, is incorporated herein by reference in its entirety.

Industrial Applicability

[0092] A radio transmission apparatus and a reference signal
25 transmission method according to the present invention are useful for improving the accuracy of channel estimation.

CLAIMS

1. A transmission apparatus configured to transmit a reference signal using one or more component carriers, the transmission apparatus comprising:
 - a generator configured to generate one or more sequences; and
 - a mapper configured to map each of the generated sequences to a frequency resource in each of the component carriers, as the reference signal, the frequency resource being comprised of one or more consecutive frequency resources,wherein
 - a maximum number of the consecutive frequency resources that are assigned to each of the component carriers is two,
 - when one component carriers is configured, one sequence is generated and the generated sequence is mapped to the frequency resource in one component carrier, and
 - when plural component carriers are configured, plural sequences are generated and the generated sequences are mapped to plural frequency resources in plural component carriers, respectively.
2. The transmission apparatus according to claim 1, wherein each of the generated sequences is mapped to a plurality of consecutive frequency resources in each of the component carriers.
3. The transmission apparatus according to claim 1, wherein, the generated sequences are cyclic shift sequences.
4. The transmission apparatus according to claim 1, wherein when the number of the component carriers is two, a number of the generated sequences is two.
5. The transmission apparatus according to claim 1, wherein when the number of the component carriers is two, a sequence number of the generated sequence for a first component carrier is different from a sequence number of the generated sequence for a second component carrier.

6. A transmission method performed by a transmission apparatus for transmitting a reference signal using one or more component carriers, the transmission method comprising:

generating one or more sequences; and

mapping each of the generated sequences to a frequency resource in each of the component carriers, as the reference signal, the frequency resource being comprised of one or more consecutive frequency resources,

wherein

a maximum number of the consecutive frequency resources that are assigned to each of the component carriers is two,

when one component carriers is configured, one sequence is generated and the generated sequence is mapped to the frequency resource in one component carrier, and

when plural component carriers are configured, plural sequences are generated and the generated sequences are mapped to plural frequency resources in plural component carriers, respectively.

7. A integrated circuit for controlling a process performed by a transmission apparatus for transmitting a reference signal using one or more component carriers, the process comprising:

generating one or more sequences,; and

mapping each of the generated sequences to a frequency resource in each of the component carriers, as the reference signal, the frequency resource being comprised of one or more consecutive frequency resources,

wherein

a maximum number of the consecutive frequency resources that are assigned to each of the component carriers is two,

when one component carriers is configured, one sequence is generated and the generated sequence is mapped to the frequency resource in one component carrier, and

when plural component carriers are configured, plural sequences are generated and the generated sequences are mapped to plural frequency resources in plural component carriers, respectively.

8. A reception apparatus configured to receive a reference signal transmitted using one or more component carriers, the reception apparatus comprising:

a receiver configured to receive the reference signal generated from one or more sequences, each of which is mapped to a frequency resource in each of the component carriers, the

- frequency resource being comprised of one or more consecutive frequency resources; and
an estimation value calculator configured to estimate a channel based on the reference signal
wherein
a maximum number of the consecutive frequency resources that are assigned to each of the
component carriers is two,
when one component carriers is configured, the reference signal is generated from one
sequence, which is mapped to the frequency resource in one component carrier, and
when plural component carriers are configured, the reference signal is generated from plural
sequences, which are mapped to plural frequency resources in plural component carriers, respectively.
9. The reception apparatus according to claim 8, wherein each of the sequences is mapped to a
plurality of consecutive frequency resources in each of component carriers.
10. The reception apparatus according to claim 8, wherein, the sequences are cyclic shift
sequences.
11. The reception apparatus according to claim 8, wherein when the number of the component
carriers is two, a number of the sequences is two.
12. The reception apparatus according to claim 8, wherein when the number of the component
carriers is two, a sequence number of a first sequence for a first component carrier is different from a
sequence number of a second sequence for a second component carrier.
13. A reception method performed by a reception apparatus for receiving a reference signal
transmitted using one or more component carriers, the reception method comprising:
receiving the reference signal

generated from one or more sequences, each of which is mapped to a frequency resource in each of the component carriers, the frequency resource being comprised of one or more consecutive frequency resources; and

estimating a channel based on the reference signal,

wherein

a maximum number of the consecutive frequency resources that are assigned to each of the component carriers is two,

when one component carriers is configured, the reference signal is generated from one sequence, which is mapped to the frequency resource in one component carrier, and

when plural component carriers are configured, the reference signal is generated from plural sequences, which are mapped to plural frequency resources in plural component carriers, respectively.

14. A integrated circuit for controlling a process performed by a reception apparatus for receiving a reference signal transmitted using one or more component carriers, the process comprising:

receiving a reference signal generated from one or more sequences, each of which is mapped to a frequency resource in each of the component carriers, the frequency resource being comprised of one or more consecutive frequency resources; and

estimating a channel based on the reference signal,

wherein

a maximum number of the consecutive frequency resources that are assigned to each of the component carriers is two,

when one component carriers is configured, the reference signal is generated from one sequence, which is mapped to the frequency resource in one component carrier, and

when plural component carriers are configured, the reference signal is generated from plural sequences, which are mapped to plural frequency resources in plural component carriers, respectively.