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(54) **TRANSMITTING DEVICE AND A METHOD OF COMMUNICATING THEREWITH, AND RECEIVING DEVICE AND A METHOD OF COMMUNICATING THEREWITH**

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H04B 7/04 (2006.01)
H04B 7/06 (2006.01)

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

CPC ***H04B 7/0456*** (2013.01); ***H04B 7/0413*** (2013.01); ***H04B 7/0469*** (2013.01); ***H04B 7/0626*** (2013.01)

(58) **Field of Classification Search**

CPC .. H04B 7/0639; H04B 7/0456; H04B 7/0469; H04B 7/0634; H04B 7/0413; H04B 7/0452; H04B 7/0626

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0257383	A1	10/2009	Lee et al.	
2010/0048233	A1	2/2010	Kim et al.	
2010/0322176	A1 *	12/2010	Chen et al.	370/329
2011/0032839	A1 *	2/2011	Chen et al.	370/252
2011/0034192	A1 *	2/2011	Lim et al.	455/501
2011/0116563	A1	5/2011	Vitthaladevuni et al.	
2011/0206024	A1 *	8/2011	Lee et al.	370/338
2011/0249713	A1 *	10/2011	Hammarwall et al.	375/220
2011/0268068	A1 *	11/2011	Jian et al.	370/329
2011/0274188	A1 *	11/2011	Sayana et al.	375/260
2011/0305263	A1 *	12/2011	Jongren et al.	375/219
2012/0003945	A1 *	1/2012	Liu et al.	455/115.1
2012/0127948	A1 *	5/2012	Chung et al.	370/329

FOREIGN PATENT DOCUMENTS

WO 2009-125956 10/2009

OTHER PUBLICATIONS

International Search Report dated Dec. 28, 2011 issued for related International Application No. PCT/KR2011/004835.

* cited by examiner

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(57) **ABSTRACT**

An embodiment of the present invention relates to a wireless communication system, and more specifically relates to a wireless communication system using multi-input and multi-output (MIMO) antennas in all transmission and reception terminals.

28 Claims, 10 Drawing Sheets

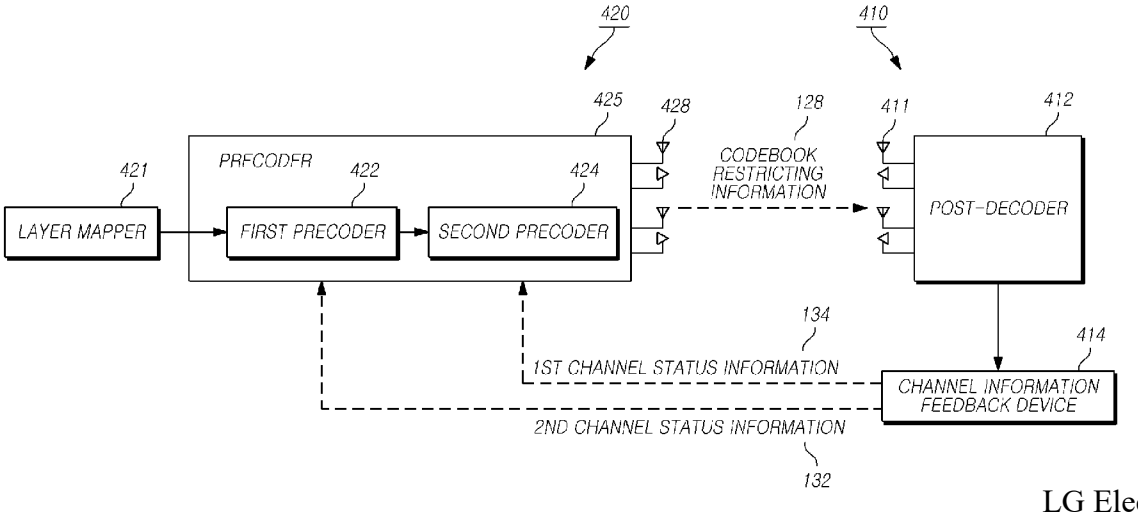


FIG. 1

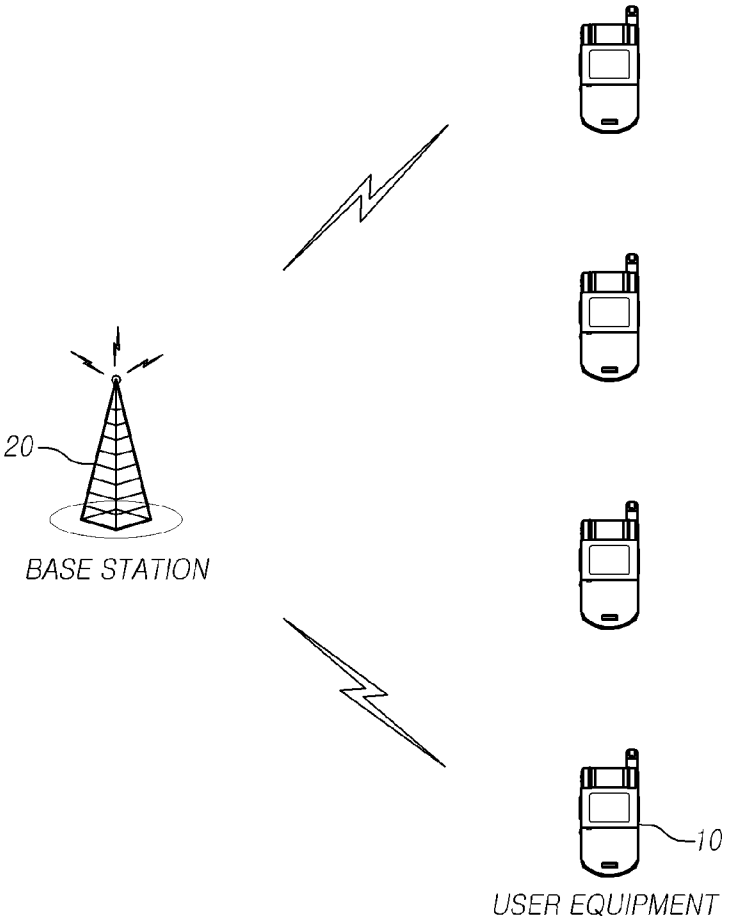


FIG.2

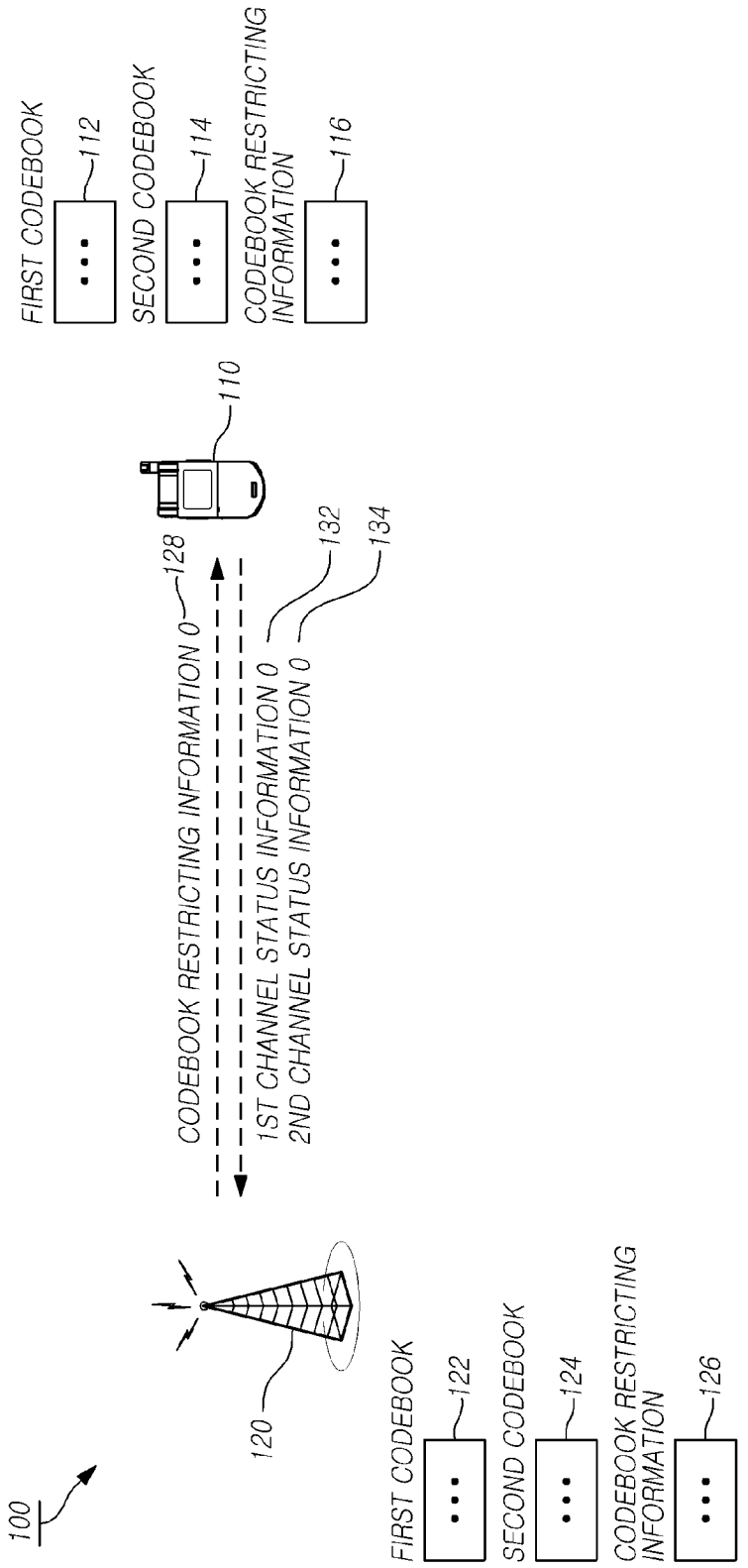

100
120
FIRST CODEBOOK
122
SECOND CODEBOOK
124
CODEBOOK RESTRICTING INFORMATION
126
CODEBOOK RESTRICTING INFORMATION 0
128
1ST CHANNEL STATUS INFORMATION 0
132
2ND CHANNEL STATUS INFORMATION 0
134
110
FIRST CODEBOOK
112
SECOND CODEBOOK
114
CODEBOOK RESTRICTING INFORMATION
116

FIG.3

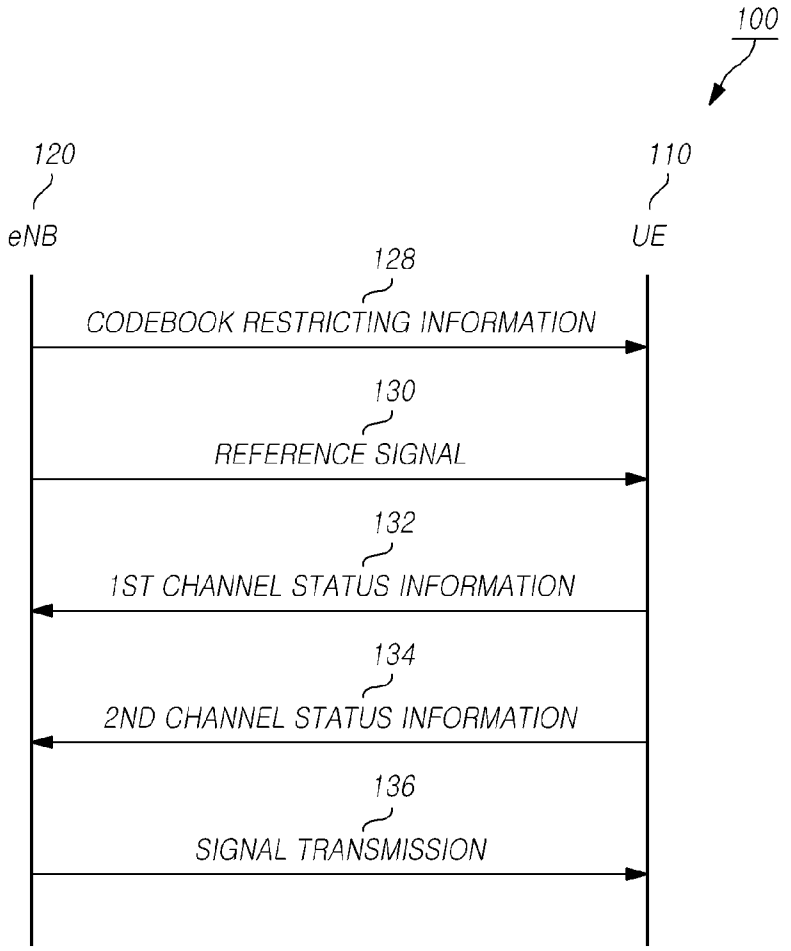

100
120
eNB
110
UE
128
CODEBOOK RESTRICTING INFORMATION
130
REFERENCE SIGNAL
132
1ST CHANNEL STATUS INFORMATION
134
2ND CHANNEL STATUS INFORMATION
136
SIGNAL TRANSMISSION

FIG.4

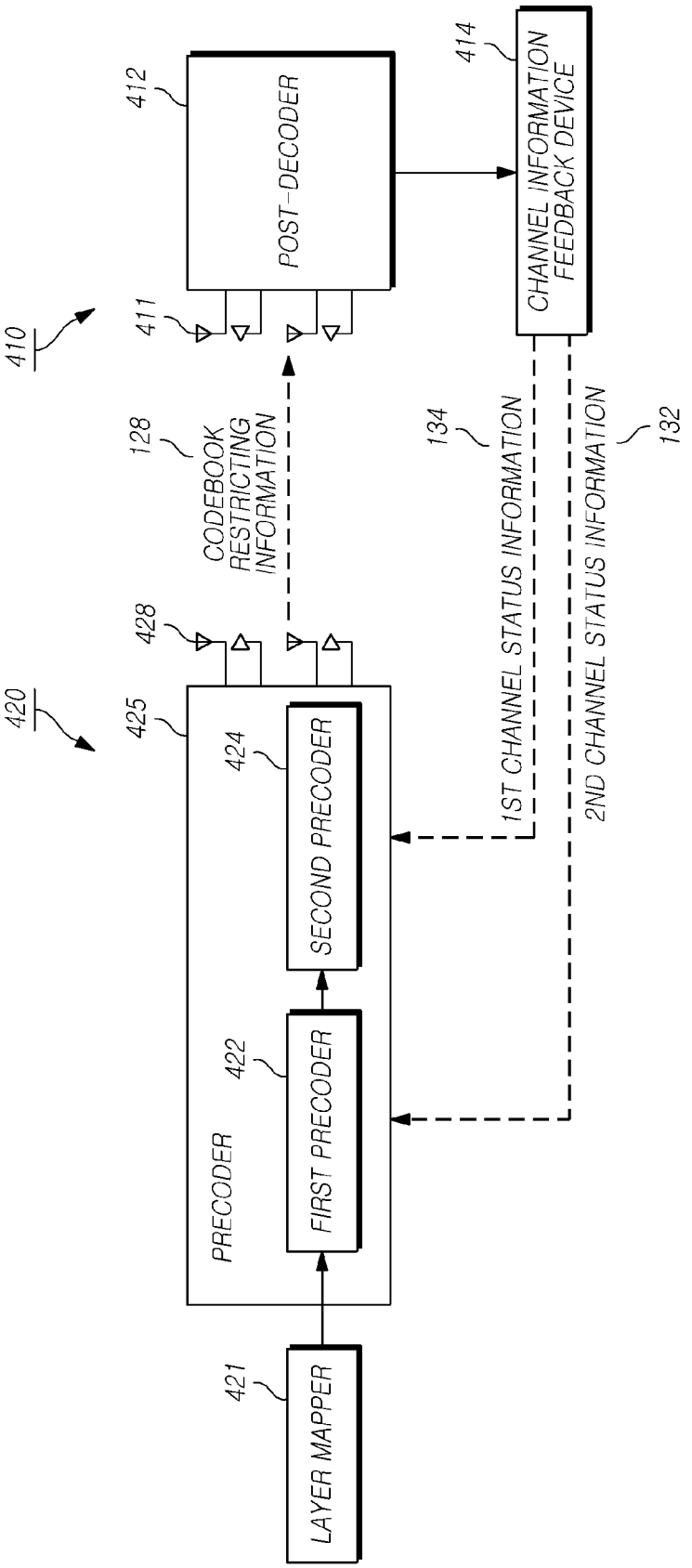
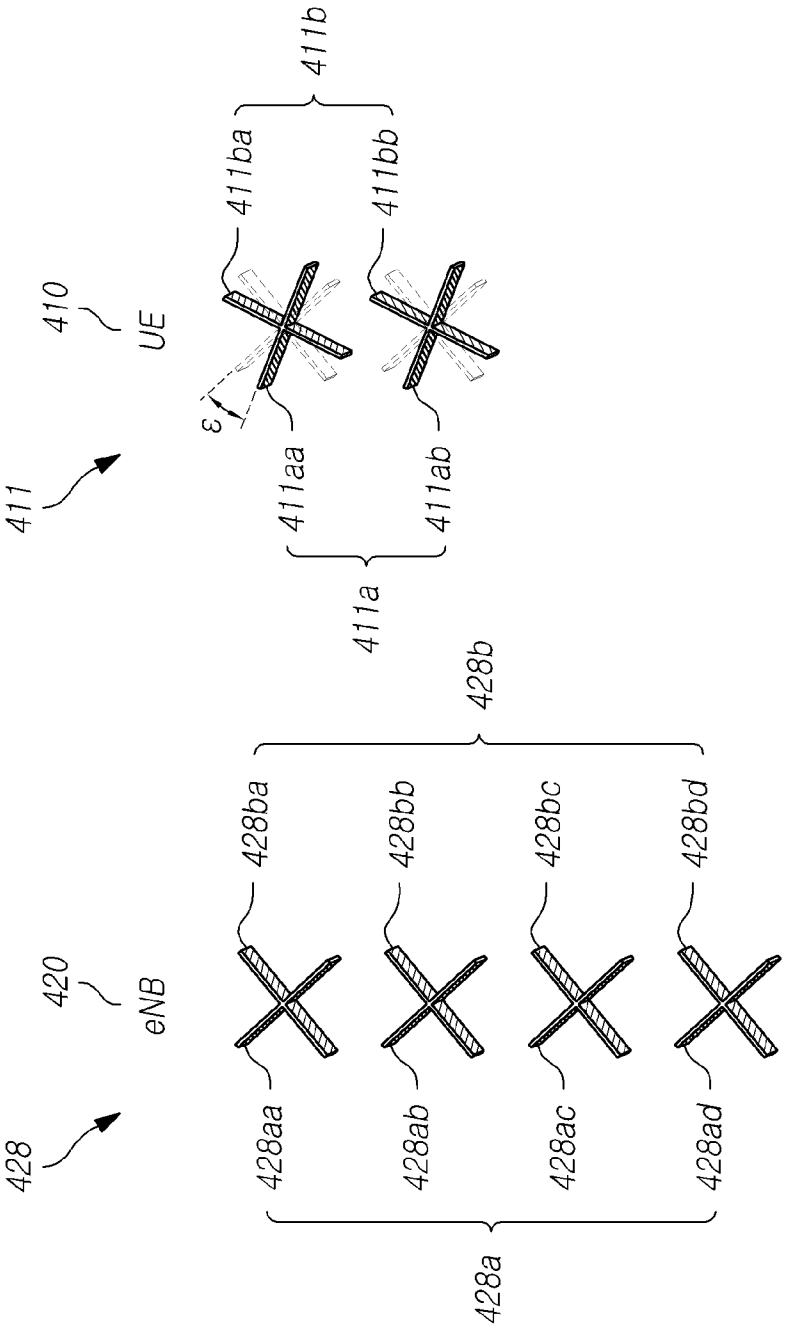

410
411
412
POST-DECODER
414
CHANNEL INFORMATION FEEDBACK DEVICE
128
CODEBOOK RESTRICTING INFORMATION
134
1ST CHANNEL STATUS INFORMATION
132
2ND CHANNEL STATUS INFORMATION
420
425
PRECODER
428
422
FIRST PRECODER
424
SECOND PRECODER
421
LAYER MAPPER

FIG.5


411
410
UE
411ba
411bb
411b
ε
411aa
411ab
411a
428
420
eNB
428ba
428bb
428bc
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428aa
428ab
428ac
428ad
428a

FIG.6

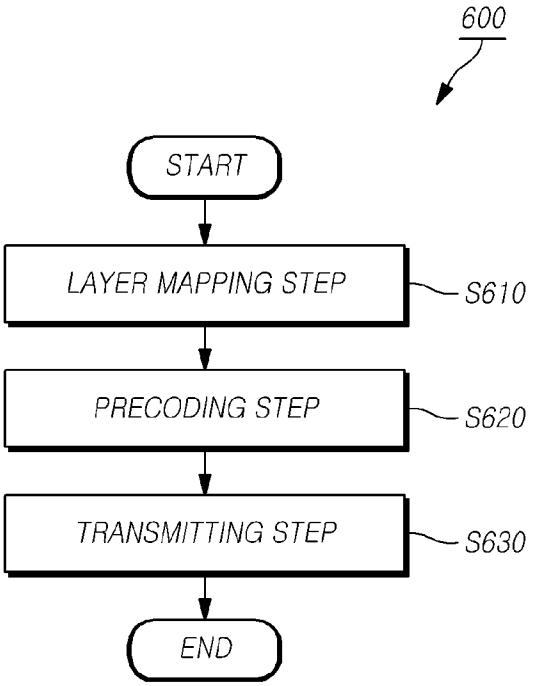

600
START
LAYER MAPPING STEP
S610
PRECODING STEP
S620
TRANSMITTING STEP
S630
END

FIG. 7

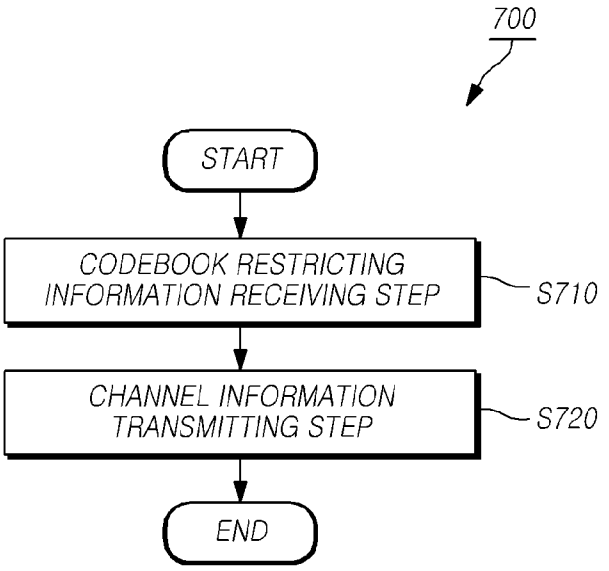

700
START
CODEBOOK RESTRICTING INFORMATION RECEIVING STEP
S710
CHANNEL INFORMATION TRANSMITTING STEP
S720
END

FIG. 8

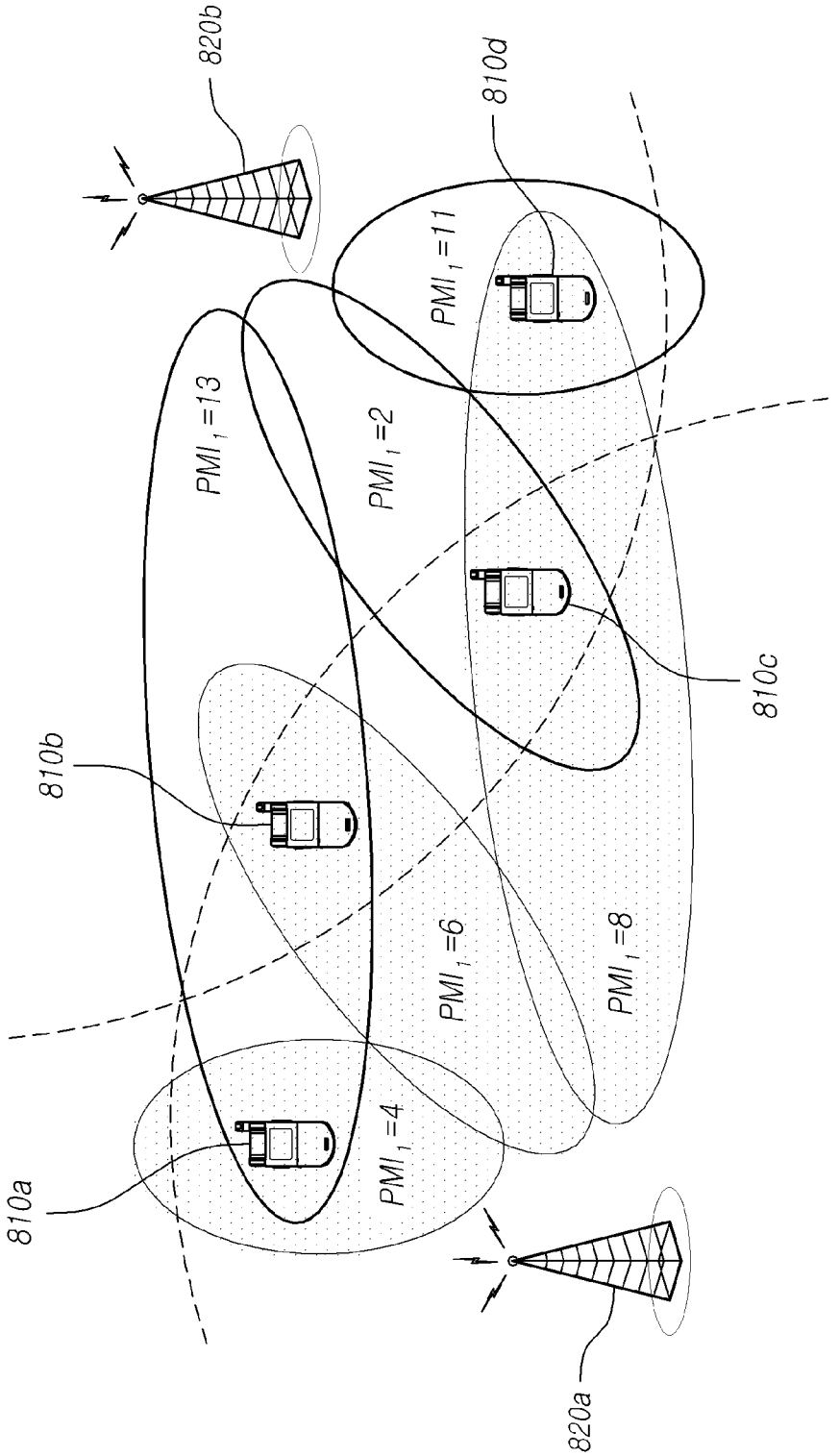

820b
810d
PMI$_1$=11
PMI$_1$=13
PMI$_1$=2
810c
810b
PMI$_1$=6
PMI$_1$=8
PMI$_1$=4
810a
820a

FIG. 9

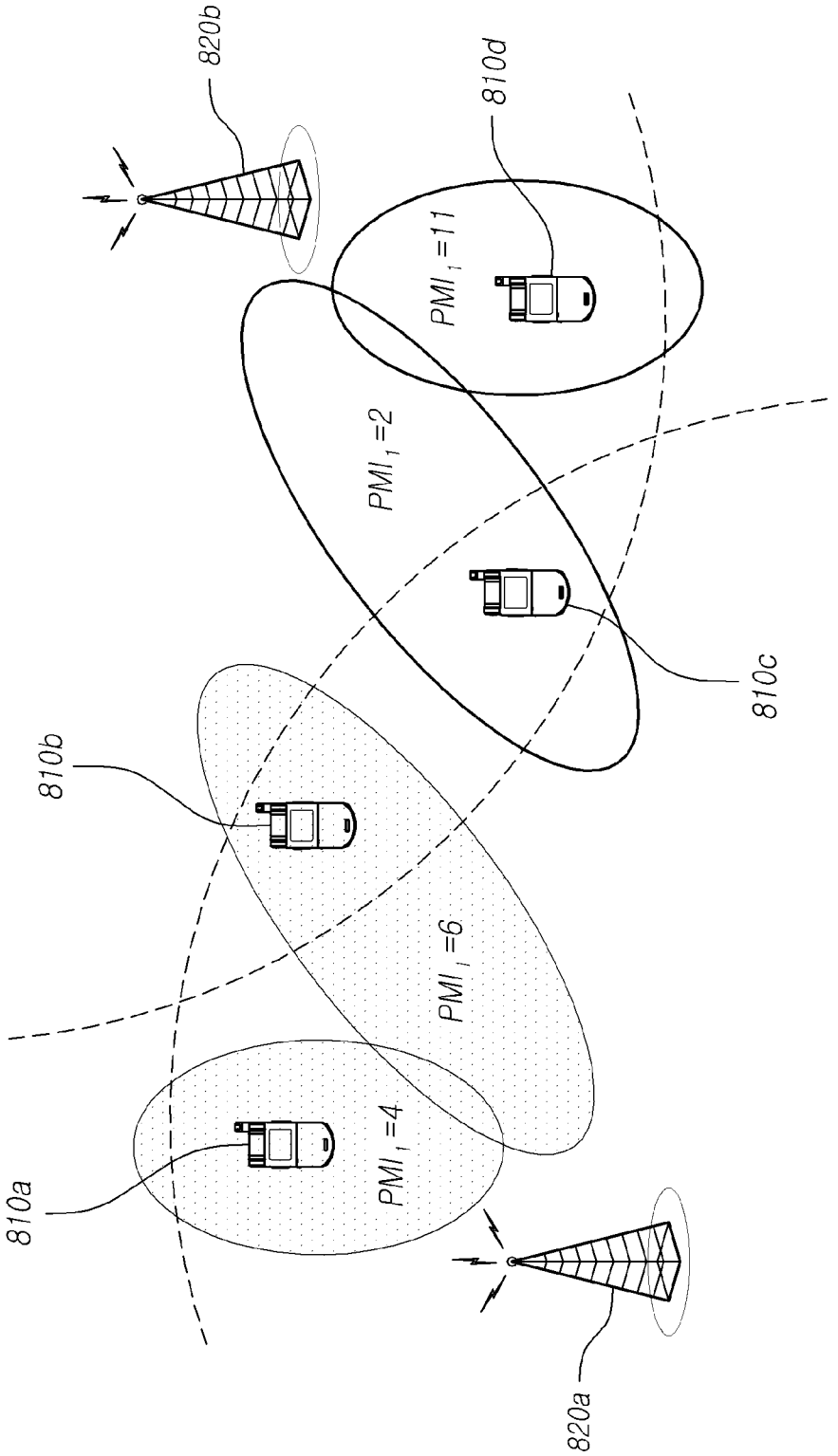
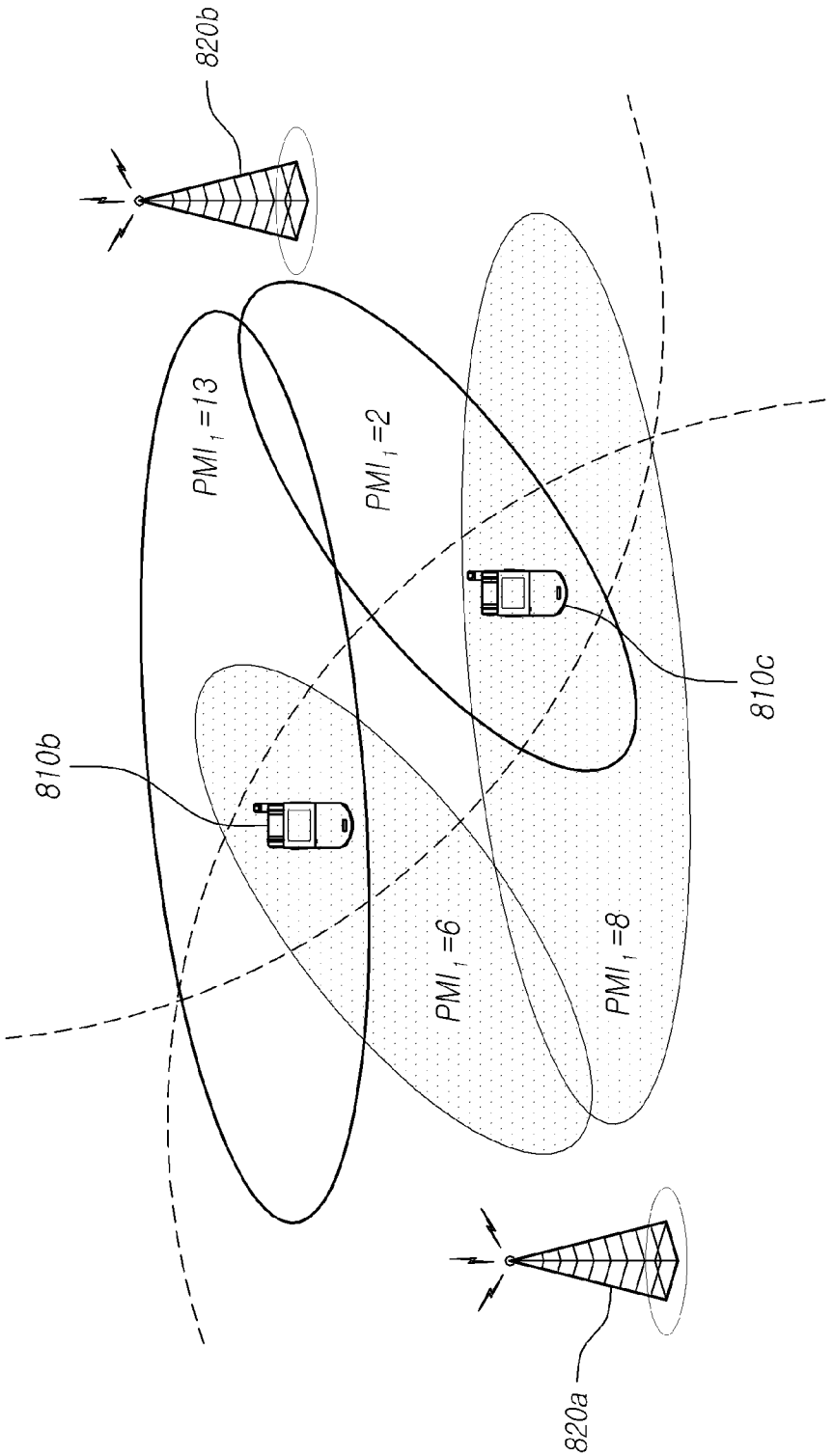


FIG. 10



TRANSMITTING DEVICE AND A METHOD OF COMMUNICATING THEREWITH, AND RECEIVING DEVICE AND A METHOD OF COMMUNICATING THEREWITH

CROSS-REFERENCE TO RELATED APPLICATION

This application is the National Stage Entry of International Application No. PCT/KR2011/004835, filed on Jul. 1, 2011, and claims priority from and the benefit of Korean Patent Application No. 10-2010-0064573, filed on Jul. 5, 2010, all of which are hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

1. Field

The present invention relates to a wireless communication system, and more particularly, to a wireless communication system that uses multiple input multiple output (MIMO) in both a transmitting end and a receiving end.

2. Discussion of the Background

As communication systems have developed, various wireless terminals have been utilized by consumers, such as companies and individuals.

A current mobile communication system, such as 3GPP, LTE (Long Term Evolution), LTE-A (LTE Advanced), and the like, may be a high capacity communication system capable of transmitting and receiving various data such as image data, wireless data, and the like, beyond providing a sound-based service. Accordingly, there is a desire for a technology that transmits high capacity data, which is comparable with a wired communication network. Also, the system is required to minimize loss of information and increase transmission efficiency of the system so as to enhance performance of the system.

SUMMARY

In accordance with an aspect of the present invention, there is provided a communication method of a transmitting device including a first precoder and a second precoder, the method including: determining first information to restrict a precoding matrix from being used as a first precoding matrix of the first precoder, and second information to restrict a precoding matrix from being used as a second precoding matrix of the second precoder in a corresponding codebook with respect to each layer; and transmitting, to a receiving device, codebook restricting information including at least one of the determined first information and second information.

In accordance with another aspect of the present invention, there is provided a transmitting device, the device including: a layer mapper to map a codeword to a layer; a precoder including a first precoder and a second precoder that performs precoding on a data symbol corresponding to the codeword mapped to the layer by the layer mapper, using a first precoding matrix and a second precoding matrix selected from a corresponding codebook; and an antenna array to transmit signals output from the precoder, and the codeword includes at least one of first information to restrict a precoding matrix from being used as the first precoding matrix and second information to restrict a precoding matrix from being used as the second precoding matrix in the corresponding codebook with respect to each layer.

In accordance with another aspect of the present invention, there is provided a communication method of a receiving device in a wireless communication system, the method including: receiving codebook restricting information including at least one of first information to restrict a precoding matrix from being used as a first precoding matrix and second information to restrict a precoding matrix from being used as a second precoding matrix for each layer; and transmitting, to a transmitting device, 1st channel status information indicating a first precoding matrix and 2nd channel status information indicating a second precoding matrix, the first precoding matrix and the second precoding matrix being selected, based on the codebook restricting information, from among precoding matrices that are not restricted from being used as the first precoding matrix or the second precoding matrix in a codebook.

In accordance with another aspect of the present invention, there is provided a receiving device in a wireless communication system, the device including: an antenna array to receive, as codebook restricting information, at least one of first information to restrict a precoding matrix from being used as a first precoding matrix and first information to restrict a precoding matrix from being used as a second precoding matrix with respect to each layer; and a channel information feedback device to transmit, to a transmitting device, 1st channel status information indicating a first precoding matrix and 2nd channel status information indicating a second precoding matrix, the first precoding matrix and the second precoding matrix being selected, based on the codebook restricting information, from among precoding matrices that are not restricted from being used as the first precoding matrix of the second precoding matrix in a codebook.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a wireless communication system according to embodiments of the present invention;

FIG. **2** is a diagram illustrating a wireless communication system in which a base station and a user equipment exchange codebook restricting information and channel status information in a case of codebook restriction;

FIG. **3** is a flowchart further illustrating a reference signal and signal transmission in the wireless communication system that exchanges codebook restricting information and channel status information of FIG. **2**;

FIG. **4** is a block diagram illustrating a base station and a user equipment in a MIMO wireless communication system according to an embodiment of the present invention;

FIG. **5** is a diagram illustrating a channel between a base station and a user equipment that use a polarized antenna array of FIG. **4**;

FIG. **6** is a flowchart illustrating a communication method of a transmitting device according to another embodiment of the present invention; and

FIG. **7** is a flowchart illustrating a communication method of a receiving device according to another embodiment of the present invention.

FIGS. **8** through **10** are conceptual diagrams illustrating a process of controlling inter-cell interference using a codebook restriction scheme in a wireless communication system according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Hereinafter, exemplary embodiments of the present invention will be described with reference to the accompanying drawings. In the following description, the same elements

will be designated by the same reference numerals although they are shown in different drawings. Further, in the following description of the present invention, a detailed description of known functions and configurations incorporated herein will be omitted when it may make the subject matter of the present invention rather unclear.

FIG. **1** is a block diagram illustrating a wireless communication system according to embodiments of the present invention.

The wireless communication system may be widely installed so as to provide various communication services such as voice data, packet data, and the like.

Referring to FIG. **1**, the wireless communication system may include a user equipment (UE) **10** and a base station (BS) **20**.

The user equipment **10** may be an inclusive concept indicating a user terminal utilized in a wireless communication, including a UE (User Equipment) in WCDMA, LTE, HSPA, and the like, and an MS (Mobile Station), a UT (User Terminal), an SS (Subscriber Station), a wireless device and the like in GSM.

The base station **20** or a cell may generally refer to a station where communication with the user equipment **10** is performed, and may also be referred to as a Node-B, an eNB (evolved Node-B), a BTS (Base Transceiver System), an access point, a relay node, and the like.

In the specifications, the user equipment **10** and the base station **20** are used as two inclusive transceiving subjects to embody the technology and technical concepts described in the specifications, and may not be limited to a predetermined term or word.

An embodiment of the present invention may be applicable to an asynchronous wireless communication scheme that is advanced through GSM, WCDMA, and HSPA, to be LTE (Long Term Evolution) and LTE-advanced, and may be applicable to a synchronous wireless communication scheme that is advanced through CDMA and CDMA-2000, to be UMB. Embodiments of the present invention may not be limited to a specific wireless communication scheme, and may be applicable to all technical fields to which a technical idea of the present invention is applicable.

The wireless communication system according to embodiments of the present invention may support an uplink and/or downlink HARQ (Hybrid Automatic Repeat request), and may use a CQI (channel quality indicator) for link adaptation. Also, a multiple access scheme for downlink transmission and a multiple access scheme for uplink transmission may be different from each other. For example, a downlink may use OFMDA (Orthogonal Frequency Division Multiple Access) and an uplink may use SC-FDMA (Single Carrier-Frequency Division Multiple Access).

To support high-speed information transmission for the user, the wireless communication system may consider using a Multiple Input Multiple Output (MIMO) scheme that transfers information through the same band using an antenna array including a multi-antenna.

To embody an effective MIMO system, a MIMO wireless communication system may need to provide, to a transmitting device, information associated with a propagation channel or information associated with a precoder or a precoding matrix (hereinafter referred to as a precoding matrix) appropriate for a propagation channel, to increase transmission capacity. In this example, the former requires a large amount of feedback overhead, whereas the latter requires a relatively small amount of feedback overhead.

In the latter case, each of the user equipment **10** and the base station **20** stores a codebook that defines N available precoding matrices, and expresses an index or an indicator indicating or indexing (corresponding to) each precoding matrix, and identification. Each user equipment **10** selects a precoding matrix appropriate for a propagation channel, and transmits an index indexing the selected precoding matrix to the base station **20**. The base station **20** receives precoding matrix indices from each user equipment **10**, and selects a MIMO mode or a user equipment or performs precoding based on the received precoding matrix indices.

In this example, as a size of a codebook becomes larger since a number of available precoding matrices is large, the precoding performance of the base station **120** increases. However, an amount of feedback overhead of the user equipment **10** required for reporting the precoding matrices or corresponding indices to the base station **20** may be increased. Therefore, when a large size codebook is used, a codebook restriction or a codebook subset restriction that restricts at least one precoding matrix in a codebook may need to be used for more effective precoding.

The codebook restriction is a scheme that generates a codebook including various precoding matrices, selects a precoding matrix to be used/not used in the codebook for each cell or each user equipment, and uses different codebooks for each cell or each user equipment based on codebook restricting information (hereinafter referred to as "codebook restricting information") associated with a precoding matrix to be not used. When the codebook restriction scheme is used, the whole wireless communication system has a large size codebook, but a codebook that is used by each cell or each user equipment is configured of subsets of the codebook, and has a small size, and is configured of only precoding matrices appropriate for a given environment and thus, a precoding gain may be increased.

For example, when downlink MIMO transmission between the base station **20** and the user equipment **10** simultaneously performs transmission with respect to up to 4 layers, the user equipment **10** may transfer, to the base station **20** using a rank indicator (RI), a number of layers that the user equipment **10** is capable of receiving. In this example, 16 precoding matrices may be designated for each rank during the downlink MIMO transmission between the base station **20** and the user equipment **10**, and a total of 64 precoding matrices may be configured as shown in Table 1.

TABLE 1

	PMI				
RI	0	1	2	. . .	15
1	a0	a1	a2	. . .	a15
2	a16	a17	a18	. . .	a31
3	a32	a33	a34	. . .	a47
4	a48	a49	a50	. . .	a63

In a case in which the codebook restriction is used, when whether a precoding matrix is to be used is determined for each of the 64 precoding matrices and codebook restricting information is transmitted based on a bitmap format that designates whether each precoding matrix is to be used using 1 bit, a total of 64 bits may be required. For example, a corresponding order of an available precoding matrix is expressed to be 1, and a corresponding order of an unavailable precoding matrix is expressed to be 0, as shown in [001010010 . . . 010].

The user equipment **10** may report, to the base station **20** as channel status information, 64 indices corresponding to the total of 64 precoding matrices using a total of 6 bits. In this

example, when a codebook restriction that restricts the use of 32 precoding matrices from among the 64 precoding matrices is used, a number of information to be distinguished by 6 bits may be decreased from 64 to 32 and thus, a degree of reliability of a feedback signal may be increased. The user equipment **10** may decrease a number of bits that expresses the indices corresponding to the precoding matrices to 5 bits so as to reduce an amount of feedback overhead of the channel status information.

In addition, the use of precoding matrices that are predicted to cause inter-cell interference may be restricted by the codebook restriction and thus, the inter-cell interference may be prevented in advance. In particular, when a beamforming like precoding that is based on a location of each user equipment is performed, a user equipment located in a cell edge may cause serious inter-cell interference. To prevent the inter-cell interference in advance, a codebook restriction may be performed for each cell and thus, the inter-cell interference may be controlled.

The base station **20** may use a multistage precoder including at least two precoders. The codebook restriction that restricts a precoding matrix to be used for each precoder may also be applicable, when the multistage precoder is used. In this example, a number of precoding matrices is generally increased and a number of bits to be used for codebook restricting information for the codebook restriction may also be increased.

In particular, a high signaling and feedback overhead may be required to support high speed information transmission in an uplink or a downlink and thus, a number of bits that the base station **20** uses to inform each user equipment **10** of the codebook restriction may need to be reduced.

The wireless communication system according to embodiments of the present invention has been described. Hereinafter, with reference to FIGS. **2** and **3**, a process will be described in which a base station and a user equipment exchange codebook restricting information and channel status information in a wireless communication system when a multistage precoder is used in a case of codebook restriction.

FIG. **2** illustrates a wireless communication system in which a base station and a user equipment exchange codebook restricting information and channel status information in a case of codebook restriction.

Referring to FIG. **2**, a wireless communication system **100** may include the base station **120** and may include at least one user equipment existing in the wireless communication system **100**, for example, n user equipments **110**, like the wireless communication system of FIG. **1**. Although the user equipments **110** may correspond to user equipments that are currently being connected or that attempt additional connection, a single user equipment is illustrated in FIG. **2** for ease of descriptions.

The base station **120** includes a multistage precoder including at least two precoders, that is, first and second precoders. The base station **120** stores a first codebook **122** that expresses N first precoding matrices to be used for the first precoder and first indices indexing the first precoding matrices and a second codebook **124** that expresses M second precoding matrices to be used for the second precoder and second indices indexing the second precoding matrices.

The base station stores a restriction book **126** including ranks and an index (hereinafter referred to as a restriction index) corresponding to each pair of a first index and a second index with respect to each rank. The base station **120** determines a precoding matrix to be used/not used for each cell or for each user equipment, and may transmit, to the user equipment **110**, codebook restricting information **128** associated with the precoding matrix to be not used. In this example, the codebook restricting information **128** includes first information that restricts a precoding matrix from being used as a first precoding matrix and second information that restricts a precoding matrix from being used as a second precoding matrix in the first and second codebooks **122** and **124** with respect to each layer.

FIG. **3** is a flowchart further illustrating a reference signal and signal transmission in the wireless communication system that exchanges codebook restricting information and channel status information of FIG. **2**.

Referring to FIG. **3**, for transmission and reception of data between the user equipment **110** and the base station **120**, the base station **120** at a transmitter side transmits a reference signal **130** as further illustrated in FIG. **3**, and the user equipment **110** at a receiver side estimates a channel using the reference signal **130**. For example, in a case of downlink transmission, the user equipment **110** may estimate a downlink channel. In particular, in a case of OFDM transmission, the user equipment **110** may estimate a channel of each subcarrier. Conversely, in a case of uplink transmission, the base station **120** may estimate an uplink channel.

For the channel estimation, a predetermined signal or symbol may be inserted into a frequency-domain grid at regular or irregular intervals. In this example, the predetermined signal or symbol may be referred to as a reference signal or a reference symbol, a pilot symbol, and the like. In the specifications, the predetermined signal or symbol is referred to as a reference signal, but this may not be limited thereto. The reference signal **130** may not be used for only the estimation of the frequency-domain channel, but may be used for estimation of a location required for wireless communication between a user equipment and a base station, transmission and reception of control information, transmission and reception of scheduling information, transmission and reception of feedback information, and the like.

There may be various types of reference signals for downlink or uplink transmission, and new reference signals for various purposes have been defined and discussed. For example, reference signals for the uplink transmission may include a DM-RS (Demodulation RS), an SRS (Sounding RS), and the like. Reference signals for the downlink transmission may include a DM-RS (Demodulation RS), CRS (Cell-specific RS), an MBSFN RS, a UE-specific RS, and the like. Also, a CSI-RS is used as a reference signal that a base station transmits to obtain channel status information (CSI) of a center cell or adjacent cells from the user equipment **110** in a case of downlink transmission. The CSI-RS may be used for reporting a CQI (Channel Quality Indicator)/PMI (Precoder Matrix Indicator)/RI (Rank Indicator), and the like. The CSI-RS may be cell-specific so as to be distinguished for each cell included in a base station that transmits the CSI-RS, and may need to be sufficiently scattered in a frequency and a time for a low overhead.

Referring again to FIG. **2**, the user equipment **110** stores a first codebook **112** that expresses N first precoding matrices used for a first precoder and first indices indexing the first precoding matrices and a second codebook **114** that expresses M second precoding matrices used for a second precoder and second indices indexing the second precoding matrices. The first codebook **112** and the second codebook **114** may be identical to the first codebook **122** and the second codebook **124** stored in the base station **120**, respectively.

The user equipment **110** stores a restriction book **116**, which will be described with reference to Table 4, including ranks and a plurality of indices (hereinafter referred to as a restriction index) corresponding to each pair of a first index

and a second index included in each rank. The restriction book **116** stored in each user equipment **110** may be identical to the restriction book **126** stored in the base station **120**.

The user equipment **110** may receive codebook restricting information **128** from the base station **120**. The codebook restricting information **128** includes at least one of first information that restricts a precoding matrix from being used as a first precoding matrix and second information that restricts a precoding matrix from being used as a second precoding matrix in first and second codebooks for each layer.

The user equipment **110** determines, based on the first information included in the codebook restricting information **128**, a first precoding matrix excluding precoding matrices that are restricted from being used as a first precoding matrix, and reports/feeds back 1st channel status information **132** associated with the determined precoding matrix to the base station **120**. Also, each user equipment **110** determines, based on the second information included in the codebook restricting information **128**, a second precoding matrix excluding precoding matrices that are restricted from being used as a second precoding matrix, and reports/feeds back 2nd channel status information **134** associated with the determined second precoding matrix to the base station **120**.

The base station **120** determines precoding matrices of the first precoder and the second precoder from the first codebook **122** and the second codebook **124** based on the channel status information **132** and **134** reported from each user equipment **110**, and performs precoding of data symbols using the precoding matrices.

Referring again to FIG. **3**, the base station **120** transmits a precoded signal **136** to the user equipment **110** as illustrated in FIG. **3**. Conversely, the user equipment **110** receives the signal **136** and decodes the signal into original data.

The process has been described in which a base station and a user equipment exchange codebook restricting information and channel status information in the wireless communication system when a multistage precoder is used in a case of codebook restriction. Hereinafter, a MIMO wireless communication system that transmits and receives codebook restricting information and the channel station information will be described.

FIG. **4** is a block diagram illustrating a base station and a user equipment in a MIMO wireless communication system according to an embodiment of the present invention. FIG. **5** illustrates a channel between a base station and a user equipment that uses a polarized antenna array of FIG. **4**.

Referring to FIG. **4**, a MIMO wireless communication system may include a user equipment **410** and a base station **420**.

The user equipment **410** includes an antenna array **411** to receive a signal through a downlink channel, a post-decoder **412** to process a received signal and to decode the received signal into original data using a precoding matrix, and a channel information feedback device **414**.

The antenna array **411** may use a plurality of antennas. In this example, the antenna array **411** may form a polarized antenna array. The array may be embodied as a dual polarized antenna array in which two antennas having different polarities intersect each other so as to arrange a larger number of antennas in a limited space.

Referring to FIG. **5**, when "+" indicates a direction polarizing to the right from the vertical direction and "−" indicates a direction polarizing to the left from the vertical direction, the user equipment **410** includes a polarized antenna array **411** including two pairs of antennas in which antennas **411***aa* and **411***ab* polarized at 45 degrees from the vertical direction and antennas **411***ba* and **411***bb* polarized at −45 degrees from the vertical direction intersect to each other, respectively. In this example, the antennas **411***aa* and **411***ab* polarized at +45 degrees may be referred to as a first domain **411***a* or a first subset of a transmitting side, and the antennas **411***ba* and **411***bb* polarized at −45 degrees may be referred to as a second domain **411***b* or a second subset of the transmitting side.

Referring again to FIG. **4**, the post-decoder **412** may correspond to a first precoder **422** and a second precoder **424** of the base station **420**. The post-decoder may transfer a received reference signal to the channel information feedback device **414**.

The channel information feedback device **414** may receive a reference signal and may estimate a channel using the reference signal. The channel information feedback device **414** may generate channel information including 1st channel status information and 2nd channel station information. The channel information feedback device **414** may feed back the channel information to the base station **420**.

The base station **420** may include a layer mapper **421** to map a codeword to a layer, a precoder **425** to perform precoding of data symbols obtained through the layer mapping using a precoding matrix, and an antenna array **428** to transmit a precoded signal on air. The precoder **425** may include the first precoder **422** and the second precoder **424** to perform precoding of data symbols. In this example, the first precoder **422** and the second precoder **424** may perform precoding of data symbols using a corresponding first precoding matrix and a corresponding second precoding matrix, respectively.

The antenna array **428** of the base station **420** may use a plurality of antennas. In this example, the antenna array **428** may form a polarized antenna array. An array may be embodied as a dual polarized antenna array in which two antennas having different polarities intersect each other so as to arrange a larger number of antennas in a limited space in a wireless communication system. In this example, although it is described that the antenna arrays **411** and **428** use a dual polarized antenna array, this may not be limited thereto.

Referring to FIG. **5**, the base station **420** includes a polarized antenna array **428** including four pairs of antennas in which antennas **428***aa* through **428***ad* polarized at 45 degrees from the vertical direction and antennas **428***ba* through **428***bd* polarized at −45 degrees intersect each other, respectively. In this example, the antennas **428***aa* through **428***ad* polarized at +45 degrees are referred to as a first domain **428***a* or a first subset of a receiving side, and the antennas **428***ba* through **428***bd* polarized at −45 degrees are referred to as a second domain **428***b* or a second subset of a receiving side.

When a phase mismatch does not exist between polarized antennas of the user equipment **410** and the base station **420**, an overall channel H may be expressed as shown in Equation 1.

$$H = \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \qquad \text{Equation 1}$$

In this example, H_h denotes a channel between the first subset or the first domain **411***a* of the user equipment **410** and the first subset or the first domain **428***a* of the base station **420**, and H_v denotes a channel between the second subset or the second domain **411***b* and the second subset or the second domain **428***b* of the base station **420**.

As shown in Equation 1, when antennas polarized to different directions intersect each other and have no phase mismatch, the antennas may not affect each other. Therefore, only H_h and H_v may be estimated and thus, a channel may be

recognized. When a distance d between adjacent polarized antennas is shorter than a signal wavelength λ, a correlation between antennas may be high. In this example, H_h and H_v may be determined based on a distance d between antennas and an incident angle θ of signal propagation that arrives at the user equipment **410**.

When a phase mismatch exists between polarized antennas of the user equipment **410** and the base station **420**, for example, when pairs of antennas of the user equipment **410** are tilted to the left by ϵ, signals transmitted from each polarized domain of the base station **420** may be received by two polarized domains of the user equipment **410** and thus, inter-domain interference may occur due to a phase mismatch between the domains. Therefore, a channel may be affected by a degree of a phase error or a phase mismatch between polarized antennas of the user equipment **410** and the base station **420**, that is, by ϵ, and thus, the overall channel H may be expressed by Equation 2.

$$H = \begin{bmatrix} H_h\cos\varepsilon & -H_v\sin\varepsilon \\ H_h\sin\varepsilon & H_v\cos\varepsilon \end{bmatrix} \quad \text{Equation 2}$$

Referring again to FIG. **4**, the second precoder **424** may correct a phase mismatch to remove an effect from a phase error or a phase mismatch between polarized domains formed by the antenna array **428** including antennas intersecting in a horizontal direction and a vertical direction, and the first precoder may perform intra-domain precoding.

When a dual polarized domain is configured based on a scheme of arranging two antennas at the same location, each polarized domain may have an identical spatial channel characteristic. That is, each domain may be precoded based on an identical precoding matrix (H_h=H_v=R_0), and a signal transmitted through each polarized domain may have a different phase and size when arriving at the user equipment **410**. In this example, a first precoding matrix and a second precoding matrix used in the first precoder **422** and the second precoder **424** may be expressed by Equation 3.

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1}\underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2} \quad \text{Equation 4}$$

In Equation 3, R_0 denotes a value determined by a precoding gain when the first is domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

A size of a signal received in each domain may be determined by a precoding gain of R_0 of a first precoding matrix W_1, a second precoding matrix W_2 corrects a phase mismatch between signals received in respective domains. When an operation proceeds in this manner, a first index PMI_1 for setting the first precoding matrix W_1 and a second index PMI_2 for setting the second precoding matrix W_2 may be independently selected.

As shown in Equation 3, the precoder **425** is a precoder configured of a first precoding matrix that performs precoding using R_0 determined by a precoding gain in each of the two domains (a polarized domain or a subset of antennas) and a second precoding matrix that performs phase mismatch correction (co-phasing) between domains. Therefore, each of the two independent domains may be precoded by R_0 determined by a precoding gain, and one of the domains may be phase-corrected by Λ and may be transmitted.

In the precoder **425**, the second precoding matrix corresponds to a precoding matrix that corrects signal attenuation caused by a phase error between polarized domains in polarized antennas. Also, the second precoding matrix may correspond to a precoding matrix to correct signal attenuation caused by a phase error between polarized domains, or may correspond to a precoding matrix to correct a phase mismatch that naturally occurs between polarized antennas. The base station **420** stores a first codebook that expresses N (N is a natural number greater than or equal to 1) first precoding matrices used for the first precoder **422** and first indices indexing the first precoding matrices, and a second codebook that expresses M (M is a natural number greater than or equal to 1) second precoding matrices and second indices indexing the second precoding matrices.

Table 2 and Table 3 correspond to examples of the first codebook and the second codebook that use 16 precoding matrices and 4 precoding matrices for each rank, respectively, when the antenna array **428**, including 8 dual polarized antennas **428***a* and **428***b*, simultaneously transmits a total of 8 layers.

TABLE 2

	PMI_1				
RI	0	1	2	...	15
1	b0	b1	b2	...	b15
2	b16	b17	b18	...	b31
...	...	...	...	...	...
8	b112	b113	b114	...	b127

TABLE 3

	PMI_2			
RI	0	1	2	3
1	c0	c1	c2	c3
2	c4	c5	c6	c7
...	...	...	...	...
8	c28	c29	c30	c31

The base station **420** stores a restriction book including ranks and an index (hereinafter referred to as a restriction index) corresponding to each pair of a first index and a second index for each rank. Table 4 corresponds to a restriction book that uses 16 precoding matrices and 4 precoding matrices for each rank when the antenna array **428**, including 8 dual polarized antennas **428***a* and **428***b*, simultaneously transmits a total of 8 layers.

TABLE 4

	(PMI_1 PMI_2)									
RI	(0.0)	(0.1)	(0.2)	(0.3)	(1.0)	(1.1)	. . .	(15.1)	(15.2)	(15.3)
1	a0	a1	a2	a3	a4	a5	. . .	a61	a62	a63
2	a64	a65	a66	a67	a68	a69	. . .	a125	a126	a127
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	a448	a449	a450	a451	a452	a453	. . .	a509	a510	a511

In a case of codebook restriction, when codebook restricting information is transmitted based on a bitmap format that designates whether each precoding matrix is to be used using one bit, a total of 16×4×8=512 bits may be required for the ranks and pairs of a first index and a second index for respective ranks.

However, as described in the foregoing, a first index PMI_1 for setting a first precoding matrix W_1 and a second index PMI_2 for setting a second precoding matrix W_2 may be independently selected and thus, a codebook may be restricted independently with respect to each precoding matrix, for each rank and for each of the first precoder and the second precoder. Table 5 expresses precoders that are restricted in a restriction book when codebook restriction is determined with respect to the first index=0 (PMI_1=0) and the second index=1 (PMI_2=1) in a rank 1.

TABLE 6

	(PMI_1 PMI_2)									
RI	(0.0)	(0.1)	(0.2)	(0.3)	(1.0)	(1.1)	. . .	(15.1)	(15.2)	(15.3)
1	a0	a1	a2	a3	a4	a5	. . .	a61	a62	a63
2	a64	a65	a66	a67	a68	a69	. . .	a125	a126	a127
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	a448	a449	a450	a451	a452	a453	. . .	a509	a510	a511

Although not illustrated in Table 5, a codebook restriction may be independently performed on a first precoding matrix and a second precoding matrix with respect to 8 ranks, in the same manner as the codebook restriction performed on the rank 1.

The base station **420** determines a precoding matrix to be used/not used for each cell or for each user equipment, and transmits codebook restricting information associated with the precoding matrix to be not used to the user equipment **410**. In this example, the codebook restricting information may include first information that restricts a precoding matrix from being used as a first precoding and second information that restricts a precoding matrix from being used as a second precoding matrix in the first and second codebooks for each layer.

As shown in Table 5, when codebook restriction on a first index=0 (PMI_1=0) and a second index=1 (PMI_2=1) is determined with respect to the rank 1, codebook restricting information may include [0111111111111111] corresponding to first information and corresponding to second information in a bitmap format. As described in the foregoing, a corresponding order of an available precoding matrix is expressed to be 1, and a corresponding order of a precoding matrix not to be used is expressed to be 0. Accordingly, a codebook may be generally restricted with respect to second indices that make pairs with the first index=0 (PMI_1=0), for example, (PMI_1, PMI_2)=(0,1), (0,1), (0, 2), (0,3) in Table 5. Also, a codebook may be generally restricted with respect to the first indices that make pairs with the second index=1 (PMI_2=1), for example, (PMI_1, PMI_2)=(0,1), (1,1), . . . , (14,1), (15,1) in table 5.

When a codebook restriction on a first index=1 (PMI_1=1) and a second index=2 (PMI_2=2) is determined with respect to a rank 2, codebook restricting information may include [1011111111111111] corresponding to first information and [1101] corresponding to second information. Accordingly, a codebook may be generally restricted with respect to second indices that make pairs with the first index=1 (PMI_1=1), for example, (PMI_1, PMI_2)=(1,1), (1,1), (1,2), (1,3) in Table 5. Also, a codebook may be generally restricted with respect to the first indices that make pairs with the second index=2 (PMI_2=2), for example, (PMI_1, PMI_2)=(0,2), (1,2), . . . , (14,2), (15,2) in table 5.

When a codebook restriction on a first index=0 (PMI_1=0) and a second index=3 (PMI_2=3) is determined with respect to a rank 8, codebook restricting information may include [0111111111111111] corresponding to first information and [1110] corresponding to second information. Accordingly, a codebook may be generally restricted with respect to second indices that make pairs with the first index=0 (PMI_1=0), for example, (PMI_1, PMI_2)=(0,1), (0,1), (0, 2), (0,3) in Table 5. Also, a codebook may be generally restricted with respect to the first indices that make pairs with the second index=3 (PMI_2=3), for example, (PMI_1, PMI_2)=(0,3), (1,3), . . . , (14,3), (15,3) in table 5.

In other words, the codebook restricting information includes the first information and the second information. Accordingly, when a first precoding matrix is restricted from being used as a first precoding matrix based on the first information, the use of second precoding matrices that make pairs with the restricted first precoding matrix may be restricted. When a second precoding matrix is restricted from being used as a second precoding matrix based on the second information, the use of first precoding matrices that make pairs with the restricted second precoding matrix may be restricted.

In the same manner, codebook restricting information with respect to each of a rank 3 through a rank 7 may include first information and second information in a bitmap format. In this example, although the codebook restricting information including the first information and the second information is provided in a bitmap format, this is merely an example and may not be limited thereto.

In the same manner described in the foregoing, when the rank 1 through rank 8 transmit codebook restricting information based on the same bitmap format, a total number of bits of the codebook restricting information that independently restricts a first precoding matrix and a second precoding matrix with respect to a total of 8 ranks may be (16+4)×8=160.

The base station **420** may transmit, to the user equipment **410**, codebook restricting information that expresses codebook restriction based on a bitmap format using 20 bits for

each rank, that is, a total of 160 bits for the rank 1 through the rank 8. The codebook restricting information may be transmitted as downlink control information, for example, an RRC signal, from the base station **420** to the user equipment **410** through a Physical Downlink Shared Channel (PDSCH). In this example, the codebook restricting information may be transmitted from the base station **420** to the user equipment **410** through a Physical Downlink Control Channel (PDCCH) in addition to the PDSCH. In this example, the codebook restricting information may sequentially include first information and second information for each rank. For example, the codebook restricting information may include first information and second information associated with the rank 1, first information and second information associated with the rank 2, . . . , and first information and second information associated with the rank 8, sequentially.

The codebook restricting information may sequentially include first information for each rank, and then may sequentially include second information for each rank. For example, the codebook restricting information may sequentially include first information associated with the rank 1 through the rank 8, and then may sequentially include second information associated with the rank 1 through the rank 8. The first information and the second information included in the codebook restricting information may be independently transmitted for each rank from the base station **420** to the user equipment **410**. When a codebook is not restricted for a predetermined rank, codebook restricting information associated with the predetermined codebook may not be included.

Accordingly, when a pair of a first index and a second index is restricted, codebook restricting information of a total of 512 bits is required. However, when restriction on a first index and a second index is independently determined and transmitted, an amount of feedback overhead of the codebook restriction may be significantly reduced.

When the first precoder **422** performs intra-domain precoding using a first precoding matrix, for example, in a case where a codebook is restricted so that precoding matrices expressed to be a first index=7 (PMI_1=7) are not to be used since an intra-domain precoding gain is small, any precoding matrix that is expressed to be PMI_1=7 when the second precoder **424** performs phase mismatch correction using a second precoding matrix may not obtain an excellent precoding gain.

That is, determining restriction on a first precoding matrix that performs intra-domain precoding may take precedence over determining restriction on a second precoding matrix that performs phase mismatch correction. Therefore, when a codebook restriction is performed, only the first precoding matrix may be restricted. In this example, the codebook restricting information includes only first information that restricts the first precoding matrix and thus, a total of 16×8=128 bits may be required.

When inter-domain phase mismatch interference takes precedence in a condition of the same inter-domain interference, only the second precoding matrix may be restricted. In this example, the codebook restricting information includes only second information that restricts the second precoding matrix and thus, a total of 4×8=32 bits may be required.

As described in the foregoing, a scheme that restricts both the first precoding matrix and the second precoding matrix, independently, a scheme that restricts only the first precoding matrix, and a scheme that restricts only the second precoding matrix may be selectively used. In this example, the base station **420** may transmit, to the user equipment **410**, a restriction mode indicator of a total of 2 bits that indicates a restriction mode.

The channel information feedback device **414** of the user equipment **410** determines a first precoding matrix excluding precoding matrices that are restricted from being used as a first precoding matrix based on first information included in codebook restricting information, and reports/feeds back, to the base station **420**, 1st channel status information associated with the first precoding matrix. In the example provided in the foregoing, when [0111111111111111] corresponding to first information of a bitmap format that restricts a codebook with respect to a first index=0 (PMI_1=0) in a rank 1 is received, the channel information feedback device **414** determines a first precoding matrix from among precoding matrices corresponding to indices excluding the first index=0 (PMI_1=0), that is, from among precoding matrices excluding precoding matrices corresponding the first index=0, and reports/feeds back 1st channel status information associated with the first precoding matrix to the base station. Also, each user equipment **410** determines a second precoding matrix excluding matrices that are restricted from being used as a second precoding matrix based on second information included in codebook restricting information, and reports/feeds back, to the base station **420**, 2nd channel status information associated with the second precoding matrix. In the example provided in the foregoing, when [1011] corresponding to second information of a bitmap format that restricts a codebook with respect to a second index=1 (PMI_2=1) in a rank 2 is received, the channel information feedback device **414** determines a second precoding matrix from among precoding matrices corresponding to indices excluding the second index=1 (PMI_2=1), that is, from among precoding matrices excluding precoding matrices corresponding to the second index=1, and reports/feeds back 2nd channel status information associated with the second precoding matrix to the base station.

When [1011111111111111] corresponding to first information and [1101] corresponding to second information of a bitmap format that restrict a codebook with respect to a first index=1 (PMI_1=1) and a second index=2 (PMI_2=2) in the rank 2 are received, the channel information feedback device **414** determines a first precoding matrix and a second precoding matrix excluding precoding matrices corresponding to the first index=1 (PMI_1=1) and the second index=2 (PMI_2=2) with respect to the rank 2 as shown in Table 5, and reports/feeds back, to the base station, the associated 1st channel status information and 2nd channel status information. In the same manner, the channel information feedback device **414** may determine a first precoding matrix and a second precoding matrix excluding precoding matrices designated by first information and second information, with respect to the rank 3 through the rank 8.

As described in the foregoing, a scheme that restricts both the first precoding matrix and the second precoding matrix, independently, a scheme that restricts only the first precoding matrix, and a scheme that restricts only the second precoding matrix may be selectively used. When the base station **420** transmits, to the user equipment **410**, a restriction mode indicator of a total of 2 bits that indicates a restriction mode, the channel information feedback device **414** of the user equipment **410** may determine a first precoding matrix and a second precoding matrix based on the restriction mode, and generates and reports 1st channel status information and 2nd channel status information.

A feedback period or interval of the 1st channel status information and the 2nd channel status information may be different from each other. For example, the 1st channel status information may be fed back to the base station **420** based on a short term, and the 2nd channel status information may be fed back to the base station **420** based on a long term. In other

words, a long period/long term and a short period/short term are relative terms, and the long period/long term indicates a period that is longer than the short period/short term.

The first precoder **422** and the second precoder **424** of the base station **420** determine first and second precoding matrices based on/using channel status information reported from each user equipment **410**, and perform precoding of data symbols using the precoding matrices.

The MIMO wireless communication system that transmits and receives codebook restricting information and channel status information according to another embodiment of the present invention has been described. Hereinafter, a communication method of a transmitting device according to another embodiment of the present invention will be described.

FIG. **6** is a flowchart illustrating a communication method of a transmitting device according to another embodiment of the present invention.

Referring to FIG. **6**, a communication method **600** of a transmitting device according to another embodiment of the present invention includes a layer mapping step S**610** to map a codeword to a layer, a precoding step S**620** to perform precoding of symbols, and a transmitting step S**630** to propagate a precoded symbol into air through two or more antennas. The layer mapping step S**610**, the precoding step S**620**, and the transmitting step S**630** are identical as described in the foregoing and thus, detailed descriptions thereof will be omitted.

A communication method **600** of a base station according to another embodiment of the present invention independently performs codebook restriction on a first precoding matrix of Table 3 and a second precoding matrix of Table 4 with respect to each rank by referring to Table 5, and transmits, to the user equipment **410**, codebook restricting information that expresses codebook restriction in a bitmap format using 20 bits for each rank, that is, a total of 160 bits from a rank 1 through a rank 8. The codebook restricting information may be transmitted as downlink control information, for example, an RRC signal, from the base station **420** to the user equipment **410** through a Physical Downlink Shared Channel (PDSCH). In this example, the codebook restricting information may be transmitted from the base station **420** to the user equipment **410** through another channel such as a Physical Downlink Control Channel (PDCCH) in addition to the PDSCH.

In the layer mapping step S**610**, the codebook restricting information may be mapped to a layer as a downlink control signal.

The base station **420** determines a precoding matrix to be used/not to be used for each cell or each user equipment, and transmits codebook restricting information associated with the precoding matrix to the user equipment **410**. In this example, the codebook restricting information includes first information to restrict a precoding matrix from being used as a first precoding matrix and second information to restrict a precoding matrix from being used as a second precoding matrix in first and second codebooks for each layer.

As shown in Table 5, when codebook restriction is determined with respect to a first index=0 (PMI_1=0) and a second index=1 (PMI_2=1) in a rank 1, codebook restricting information may include [0111111111111111] corresponding to first information and [1011] corresponding to second information in a bitmap format.

The precoding step S**620** may perform precoding of a data symbol obtained through layer mapping, using a first precoding matrix and a second precoding matrix selected from a corresponding codebook. In this example, the precoding step S**620** may perform precoding of data symbols using a first precoding matrix and a second precoding matrix corresponding to a first index and a second index received from a receiving device such as a user equipment. In this example, the first index and the second index received from the receiving device may correspond to indices associated with precoding matrices selected from precoding matrices excluding precoding matrices that are restricted based on the codebook restricting information in the first codebook of Table 3 and the second codebook of Table 4.

As described in the foregoing, the transmitting device such as a base station may include at least one antenna pair in which at least one antenna polarized in one direction and at least one antenna polarized in another direction intersect each other.

In this example, as described with reference to Equation 3, a first precoding matrix performs precoding between one antenna and another antenna that intersect each other, and a second precoding matrix performs phase mismatch correction between one antenna and another antenna.

The communication method of the transmitting device has been described. Hereinafter, a communication method of a receiving device will be described.

FIG. **7** is a flowchart illustrating a communication method of a receiving device according to another embodiment of the present invention.

A communication method **700** of a receiving device may include a codebook restricting information receiving step S**710** to receive codebook restricting information from a transmitting device, and a channel information transmitting step S**720** to transmit 1st channel status information and 2nd channel status information to the transmitting device.

The codebook restricting information receiving step S**710** may receive first information to restrict a precoding matrix from being used as a first precoding matrix and second information to restrict a precoding matrix from being used as a second precoding matrix for each layer. In this example, the codebook restricting information includes first information to restrict a precoding matrix from being used as a first precoding matrix and second information to restrict a precoding matrix from being used as a second precoding matrix in a first codebook and a second codebook for each layer. The channel information transmitting step S**720** transmits, to the transmitting device, 1st channel status information indicating a first precoding matrix and 2nd channel status information indicating a second precoding matrix, the first precoding matrix and the second precoding matrix being selected, based on codebook restricting information, from precoding matrices that are not restricted from being used as a first precoding matrix or a second precoding matrix in a codebook.

Step S**710** and step S**720** will be described in detail in the following. When the receiving device receives [0111111111111111] corresponding to first information and [1011] corresponding to second information in a bitmap format that restrict a codebook with respect to a first index=0 (PMI_1=0) in a rank 1 in step S**710**, the receiving device determines a first precoding matrix from among precoding matrices corresponding to indices excluding the first index=0 (PMI_1=0), that is, from among precoding matrices excluding precoding matrices corresponding to the first index=0, as shown in Table 5, and reports/feeds back associated 1st channel status information to a base station, and determines a second precoding matrix from among precoding matrices corresponding to indices excluding the second index=1 (PMI_2=1), that is, from among precoding matrices excluding precoding matrices corresponding to the second index=1, and reports/feeds back associated 2nd channel status information to the base station in step S**720**.

Accordingly, a codebook may be generally restricted with respect to second indices that make pairs with the first index=0 (PMI_1=0), for example, (PMI_1, PMI_2)=(0,1), (0,1), (0, 2), (0,3) in Table 5. Also, a codebook may be generally restricted with respect to the first indices that make pairs with the second index=1 (PMI_2=1), for example, (PMI_1, PMI_2)=(0,1), (1,1), . . . , (14,1), (15,1) in table 5.

When the receiving device receives [1011111111111111] corresponding to first information and [1101] corresponding to second information of a bitmap format that restrict a codebook with respect to a first index=1 (PMI_1=1) and a second index=2 (PMI_2=2) in a rank 2 in step S**710**, the receiving device determines a first precoding matrix and a second precoding matrix excluding precoding matrices corresponding to the first index=1 (PMI_1=1) and the second index=2 (PMI_2=2) for the rank 2 as shown in Table 5, and reports/feeds back is associated 1st channel status information and associated 2nd channel status information to the base station in step S**720**.

Accordingly, a codebook may be generally restricted with respect to second indices that make pairs with the first index=1 (PMI_1=1), for example, (PMI_1, PMI_2)=(1,1), (1,1), (1, 2), (1,3) in Table 5. Also, a codebook may be generally restricted with respect to the first indices that make pairs with the second index=2 (PMI_2=2), for example, (PMI_1, PMI_2)=(0,2), (1,2), . . . , (14,2), (15,2) in table 5.

In other words, the codebook restricting information includes the first information and the second information. Accordingly, when a first precoding matrix is restricted from being used as a first precoding matrix based on the first information, the use of second precoding matrices that make pairs with the restricted first precoding matrix may be restricted. When a second precoding matrix is restricted from being used as a second precoding matrix based on the second information, the use of first precoding matrices that make pairs with the restricted second precoding matrix may be restricted.

In the same manner, the receiving device may determine a first precoding matrix and a second precoding matrix for each of a rank 3 through a rank 8, excluding precoding matrices designated by first information and second information.

The process in which a base station and a user equipment exchange codebook restricting information and channel status information in a wireless communication system when a codebook is restricted in a case where a multistage precoder is used, a MIMO wireless communication system that transmits and receives codebook restricting information and channel status information, and the transceiving method or communication method of the transmitting device and the receiving device in the wireless communication system have been described.

According to the embodiments of the present invention, information to restrict precoding matrices is determined for each multistage precoder, and codebook restricting information including the determined information is transmitted and thus, an amount of transmission overhead of the codebook restricting information may be reduced. According to the embodiments of the present invention, the wireless communication system uses the codebook restriction scheme and thus, inter-cell interference may be controlled.

According to a definition of a precoding matrix as described with reference to Equation 3, a precoding gain in each domain or a subset of an antenna is determined by a first precoding matrix. That is, an overall precoding gain is determined by a gain associated with the first precoding matrix and a coding gain of a second precoder matrix that performs phase mismatch correction (co-phasing) between domains or subsets. In this example, the second precoding matrix performs phase mismatch correction (co-phasing) between domains or subsets and thus, a maximum precoding gain that each user equipment is able to obtain may be determined by the first precoding matrix. In other words, power or receivable maximum power of a signal that each user equipment receives is determined by a first precoder or a first precoding matrix, and a second precoder or a second precoding matrix performs only phase correction of a signal received by each domain or subset of an antenna. Interference by multiple-access may be significantly affected by a first precoder or a first precoding matrix.

FIGS. **8** through **10** are conceptual diagrams illustrating a process of controlling inter-cell interference using a codebook restriction scheme in a wireless communication system according to embodiments of the present invention.

Referring to FIG. **8**, inter-cell interference may occur among cell edge user equipments **810***a* through **810***d* during beamforming. For example, user equipments **810***a* and **810***b* exist in a coverage of a first base station and a second base station as shown in FIG. **8** and thus, when a signal is transmitted that is precoded based on a first precoding matrix associated with a PMI_1=4 or PMI_1=6 of the first base station of a first cell **820***a*, transmission of a signal that is precoded based on a first precoding matrix associated with a PMI_1=13 of the second base station or a second cell **820***b* may cause interference.

In other words, the user equipments **810***a* and **810***b* receive both the transmitted signal that is precoded based on the first precoding matrix associated with the PMI_1=4 or PMI_1=6 of the first base station or the first cell **820***a* and the transmitted signal that is precoded based on the first precoding matrix associated with a PMI_1=13 of the second base station or the second cell **820***b* and thus, interference may occur.

Also, user equipments **810***c* and **810***d* exist in a coverage of the first base station and the second base station as shown in FIG. **8** and thus, when a signal is transmitted that is precoded based on a first precoding matrix associated with a PMI_1=8 of the first base station **820***a*, transmission of a signal that is precoded based on a first precoding matrix associated with a PMI_1=2 or a PMI_1=11 of the second base station **820***b* may cause interference.

The descriptions may be specifically provided using the user equipment **810***b* as an example as follows. The user equipment **810***b* receives a signal from both the first base station **820***a* and the second base station **820***b* as shown in FIG. **8**. The first base station **820***a* transmits a signal using the first precoding matrix corresponding to the PMI_1=6 to transmit a signal to the user equipment **810***b*, and the second base station **820***b* uses the first precoder matrix corresponding to the PMI_1=13 to transmit a signal to the user equipment **810***b*. Accordingly, as illustrated in FIG. **8**, when the second base station **820***b* transmits a signal to the user equipment **810***b* using the PMI_1=13, another user equipment **810***a* may receive multiple-access interference by the signal transmitted to the user equipment **810***b*.

When the second base station **820***b* restricts a codebook so that the first precoder matrix corresponding to the PMI_1=13 is not to be used, the user equipment **810***b* receives a signal from only the first base station **820***a* and thus, inter-cell interference due to multiple-interference may be prevented in advance.

Other user equipments **810***c* and **810***d* may receive multiple-access interference due to inter-cell interference, like the user equipments **810***a* and **810***b*.

When the first base station **820***a* restricts a codebook so that the first precoder matrix corresponding to the PMI_1=8 is not

to be used, user equipments **810***c* and **810***d* receive a signal from only the second base station **820***b* and thus, inter-cell interference due to multiple-interference may be prevented in advance.

FIG. **9** conceptually illustrates a case in which a first precoding matrix or an associated index that is expected to cause inter-cell interference is restricted by performing a codebook restriction based on the above-mentioned scheme, and a downlink MIMO is performed based on the restriction.

Referring to FIG. **9**, when each base station **820***a* and **820***b* performs a PMI_1=13 based codebook restriction that restricts the use of a first precoding matrix corresponding to a PMI_1=13 or a PMI_1=8, occurrence of inter-cell interference may be avoided or reduced as illustrated in FIG. **9**. Therefore, when a codebook restriction is applied to only a PMI_1 and is not applied to a PMI_2, inter-cell interference may be removed.

Referring to FIG. **10**, the user equipment **810***b* receives signals precoded based on a first precoding matrix associated with a PMI_1=6 of a first base station and a first precoding matrix associated with a PMI_1=13 of a second base station and thus, interference may occur. The user equipment **810***c* receives signals precoded based on a first precoding matrix associated with a PMI_1=8 of the first base station and a first precoding matrix associated with a PMI_1=2 of the second base station and thus, interference may occur. In this example, the first base station may allow the use of the PMI_1=6 and may restrict the use of the PMI_1=2, and conversely, the second base station may allow the use of the PMI_1=2 and may restrict the use of the PMI_1=6 and thus, interference between user equipments may be removed.

As another example, to remove interference between user equipments, the first base station may allow the use of the PMI_1=8 and may restrict the use of the PMI_1=13, and conversely, the second base station may allow the use of the PMI_1=13 and may restrict the use of the PMI_1=8.

As another example, to remove interference between user equipments, the first base station may allow the use of the PMI_1=6 and the PMI_1=8 and the second base station may restrict the use of the PMI_1=6 and the PMI_1=8. Conversely, the first base station may restrict the use of the PMI_1=6 and the PMI_1=8 and the second base station may allow the use of the PMI_1=6 and the PMI_1=8.

As described in the foregoing, when each base station **820***a* and **820***b* performs the PMI_1 based codebook restriction, occurrence of inter-cell interference may be avoided or reduced.

Also, when codebook restriction is applied with respect to only the PMI_2, there is an advantage in that a codebook is restricted by a small number of bits. Also, no restriction is applied to the PMI_1 that directly controls a precoding gain and thus, more precise precoding is available and a size of a codebook may be reduced.

Although the embodiments of the present invention have been described in detail, the present invention may not be limited thereto.

The embodiments of the present invention may be applied to an up/downlink MIMO system, and may be applied to all up/downlink MIMO systems such as a Coordinated multipoint transmission/reception system (CoMP), a heterogeneous network, and the like, in addition to a single cell environment.

Although a preferred embodiment of the present invention has been described for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims. Therefore, the embodiments disclosed in the present invention are intended to illustrate the scope of the technical idea of the present invention, and the scope of the present invention is not limited by the embodiment. The scope of the present invention shall be construed on the basis of the accompanying claims in such a manner that all of the technical ideas included within the scope equivalent to the claims belong to the present invention.

The invention claimed is:

1. A communication method of a transmitting device including a first precoder and a second precoder, the method comprising:

determining a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group, each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, and the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of the first precoder;

determining a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of the second precoder; and

transmitting, to a receiving device, codebook restricting information including at least one of the first bit sequence and the second bit sequence,

receiving, from the receiving device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder, and

wherein a period of receiving the information relating to the precoding matrix of the first precoder and a period of receiving the information relating to the precoding matrix of the second precoder are different from each other.

2. The method of claim **1**, further comprising:

precoding data symbols through the first precoder and the second precoder using the precoding matrix of the first precoder and the precoding matrix of the second precoder; and

transmitting the precoded data symbols,

wherein the information relating to the precoding matrix of the first precoder and the information relating to the precoding matrix of the second precoder correspond to channel status information.

3. The method of claim **1**, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

4. The method of claim **1**, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.

5. The method of claim **1**, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and

the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder

performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

6. The method of claim **5**, wherein the precoding matrix of the first precoder corresponds to W1 in the following Equation, and the precoding matrix of the second precoder corresponds to W2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

7. The method of claim **5**, wherein a number of the antenna pairs corresponds to 4.

8. The method of claim **1**, wherein the period of receiving the information relating to the precoding matrix of the first precoder is longer than the period of receiving the information relating to the precoding matrix of the second precoder.

9. A transmitting device, the device comprising:

a layer mapper to map a codeword to a layer;

a precoder configured to precode a data symbol corresponding to the codeword mapped to the layer by the layer mapper, the precoder precoding the data symbol using a precoding matrix of a first precoder and a precoding matrix of a second precoder selected from corresponding codebooks; and

an antenna array to transmit, to a receiving device, at least one of a first bit sequence and a second bit sequence, to receive, from the receiving device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder, and to transmit signals output from the precoder,

wherein the first bit sequence restricts at least one precoding matrix from a first precoding matrix group, the at least one precoding matrix of the first precoding matrix group being restricted from being used as the precoding matrix of the first precoder,

wherein the second bit sequence restricts at least one precoding matrix from a second precoding matrix group, the at least one precoding matrix of the second precoding matrix group being restricted from being used as the precoding matrix of the second precoder,

wherein each bit of the first bit sequence corresponds to one precoding matrix of the first precoding matrix group, respectively, and each bit of the second bit sequence corresponds to one precoding matrix of the second precoding matrix group, respectively, and

wherein a period of receiving the information relating to the precoding matrix of the first precoder and a period of receiving the information relating to the precoding matrix of the second precoder are different from each other.

10. The device of claim **9**, wherein the information relating to the precoding matrix of the first precoder and the information relating to the precoding matrix of the second precoder correspond to channel status information.

11. The device of claim **9**, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

12. The device of claim **9**, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.

13. The device of claim **9**, wherein the antenna array includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and

the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

14. The device of claim **13**, wherein the precoding matrix of the first precoder corresponds to W1 in the following Equation, and the precoding matrix of the second precoder corresponds to W2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

15. The device of claim **13**, wherein the first domain and the second domain intersect each other.

16. The device of claim **13**, wherein a number of the antenna pairs corresponds to 4.

17. A communication method of a receiving device in a wireless communication system, the method comprising:

receiving codebook restricting information including at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group, each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder; and

transmitting, to a transmitting device, 1st channel status information indicating the precoding matrix of the first precoder and 2nd channel status information indicating the precoding matrix of the second precoder, the precoding matrix of the first precoder and the precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted,

wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of

transmitting the information relating to the precoding matrix of the second precoder are different from each other.

18. The method of claim **17**, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

19. The method of claim **17**, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.

20. The method of claim **17**, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and

the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

21. The method of claim **20**, wherein the precoding matrix of the first precoder corresponds to W1 in the following Equation and the precoding matrix of the second precoder corresponds to W2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1}\underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

22. The method of claim **17**, wherein the period of transmitting the information relating to the precoding matrix of the first precoder is longer than the period of transmitting the information relating to the precoding matrix of the second precoder.

23. A receiving device in a wireless communication system, the receiving device comprising:

an antenna array to receive, as codebook restricting information, at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group, each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder; and

a channel information feedback device to transmit, to a transmitting device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder, the precoding matrix of the first precoder and the precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted,

wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of transmitting the information relating to the precoding matrix of the second precoder are different from each other.

24. The device of claim **23**, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

25. The device of claim **23**, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.

26. The device of claim **23**, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and

the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

27. The device of claim **26**, wherein the precoding matrix of the first precoder corresponds to W1 in the following Equation, and the precoding matrix of the second precoder corresponds to W2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1}\underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

28. The device of claim **23**, wherein the period of transmitting the information relating to the precoding matrix of the first precoder is longer than the period of transmitting the information relating to the precoding matrix of the second precoder.

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