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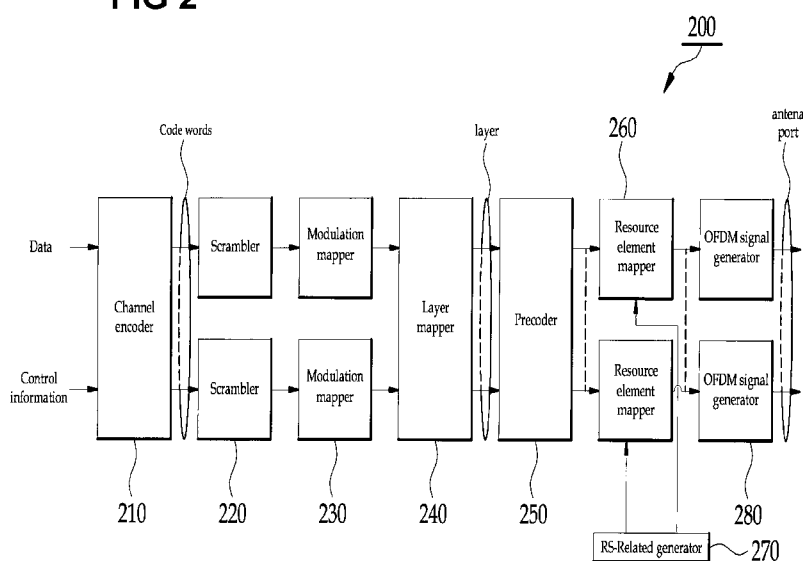
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(54) Title: BASE STATION, TERMINAL AND METHOD IN MULTI-USER MULTIPLE-INPUT MULTIPLE-OUTPUT

FIG 2

(57) Abstract: The present invention relates to Multiple Input Multiple Output(MIMO) in wireless communication system.

【DESCRIPTION】**【Invention Title】**

BASE STATION, TERMINAL AND METHOD IN MULTI-USER MULTIPLE-INPUT MULTIPLE-OUTPUT

【Technical Field】

The present invention relates to Multiple Input Multiple Output(MIMO) in wireless communication system.

【Background Art】

There are a number of multi-antenna transmission schemes or transmission such as transit diversity, closed-loop spatial multiplexing or open-loop spatial multiplexing.

【Summary of Invention】**【Technical Solution】**

In accordance with an aspect, there is provided a method or a system, comprising: A base station in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising: a layer mapper mapping a codeword to the layers where the codeword comprise the information on non-transparent MU-MIMO; a precoder precoding a mapped set of symbols using a precoding matrix; a resource element mapper mapping a precoded set of symbols for each antenna port to resource elements; and an OFDM signal generator

generating an OFDM signal for each antenna port to specific terminal among all the terminals.

In accordance with other aspect, there is provided a method in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising: signaling an information on multi-user scheduling for non-transparent MU-MIMO; generating an information related to DM-RS; and sending the information on multi-user scheduling for the non-transparent MU-MIMO and the information related to DM-RS.

In accordance with another aspect, there is provided a terminal in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising; a RF receiver complex-valued time-domain OFDM signal for each antenna port from the base station; a decoder decoding the received complex-valued time-domain OFDM signal into the original information where the decoded information includes the signaled information on multi-user scheduling for non-transparent MU-MIMO and patterned DM-RSs from the base station; and a controller configured to control interference cancellation using the signaled information and patterned DM-RSs.

【Description of Drawings】

FIG.1 is a system configuration of MU-MIMO(Multi-User Multi-Input Multi-Output) wireless communication system.

FIG.2 is the block diagram of a base station according to the other

embodiment

FIG.3 is list of information on non-transparent MU-MIMO according to another embodiment.

FIG. 4 is a pattern of DM-RS in the resource block for rank 2 and 4.

FIG.5 is the diagram of a RS resource allocator and a RS generator according to another embodiment.

FIG.6 is the flowchart of a method for DL control signaling of non-transparent MU-MIMO according to another embodiment.

FIG.7 is the block diagram of a terminal according to another embodiment

FIG.8 is the flowchart of a method for operating received control signal and DM-RS in MU-MIMO wireless communication system.

It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the drawings have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements for purposes of promoting and improving clarity and understanding. Further, where considered appropriate, reference numerals have been repeated among the drawings to represent corresponding or analogous elements.

【Mode for Invention】

Hereinafter, embodiments of the present invention will be described in detail with reference to the attached drawings.

There are two types of multiple-input and multiple-output(MIMO) such as a single-user MIMO(SU-MIMO) and a multi-user MIMO(MU-MIMO).

In single-user MIMO(SU-MIMO), all the spatial layers within allocated resource blocks are addressed to the same mobile terminal or UE. In the case of multi-user MIMO(MU-MIMO), different spatial layers can be addressed to different mobile terminals or UEs. Under correlated antenna scenarios, multi-user MIMO(MU-MIMO) can improve cell capacity as orthogonal spatial beams can be created for mobile terminals at different spatial locations in the cell.

For example, the LTE(Long Term Evolution) system supports multi-user MIMO(MU-MIMO) for the correlated channel conditions with single layer transmission to the mobile terminal. The LTE(Long Term Evolution) system does not limit the number of mobile terminals that can be scheduled using the same resource blocks.

FIG.1 is a system configuration of MU-MIMO(Multi-User Multi-Input Multi-Output) wireless communication system according to one embodiment.

Referring to FIG.1, a multi-user MIMO(MU-MIMO) wireless communication system 100 is a set of advanced MIMO technologies that exploit the availability of multiple independent radio terminals 120 to 140 in order to enhance the communication capabilities of each individual terminal.

As described above, in multi-user MIMO(MU-MIMO) 100, different spatial layers of a base station 110 can be addressed to different mobile terminals or UEs 120 to 140.

The base station 110 refers to a fixed station communicating with the terminals 120 to 140. The base station 110 may be a Node-B, eNB(evolved Node-B), BTS(Base Transceiver System), Access Point or Relay Node.

The terminals 120 to 140 refer to the user terminal in wireless communication system. The terminals 120 and 130 may be UE(User Equipment) of WCDMA, LTE and HSPA, MS(Mobile Station) of GSM, UT(User Terminal), SS(Subscriber Station) or a wireless device and so on.

The term layer is synonymous with stream. For spatial multiplexing, at least two layers must be used. The number of layers of the base station 110 is always less than or equal to the number of antennas.

The multi-user MIMO(MU-MIMO) wireless communication system 100 is non-transparent applied to several embodiment.

The term "non-transparent" in respect of MU-MIMO wireless communication system 100 means that one terminal 120 receiving a data transmission knows at least whether or not another terminal 130 is co-scheduled in the same resource blocks. For non-transparent MU-MIMO 100, downlink signaling needs to indicate to one terminal 120 whether a downlink data transmission to another terminal 130 is taking place in the same resource block. For

transparent MU-MIMO, no downlink signaling is provided to indicate to a terminal whether a downlink transmission to another terminal is taking place in the same resource block.

In short, the terminals 120 to 140 must be informed of which DM-RS pattern is being used. The base station 110 can inform the terminals 120 to 140 of the DMRS pattern used either by dynamic signaling or by higher layer signaling. By non-transparent MU-MIMO 100, the terminals 120 to 140 can know other scheduled terminal's information.

The main advantage of non-transparent MU-MIMO 100 is that assistance may be given to the terminals 120 to 140 to support more advanced receiver processing. This can include techniques such as selecting optimised MMSE combining weights in the receiver, or non-linear interference cancellation techniques.

Multiple access MIMO, MIMO-SDMA, many transmit antenna MIMO-SDMA, Cooperative MIMO, Network MIMO and Ad-hoc MIMO are all family terminologies within MU-MIMO applied to several embodiments as described below.

FIG.2 is the block diagram of a base station in MU-MIMO wireless communication system according to the other embodiment.

Referred to FIG.2, the base station 200 in MU-MIMO wireless communication system according to the other embodiment comprises a channel encoder 210, a

scrambler 220, a modulation mapper 230, a layer mapper 240, a precoder 250, a resource element mapper 260, a RS-related apparatus 270 and a OFDM signal generator 280. The channel encoder 210, the scrambler 220 and the modulation mapper 230 may be omitted or combined with other elements.

The channel encoder 210 encodes the data from the higher layer and control information into coded bits. The control information includes not only general information on downlink scheduling assignments, uplink scheduling grants and power control commands but also information on non-transparent MU-MIMO. The information on non-transparent MU-MIMO included in coded control information by the channel encoder 210 is described below referring to FIG.3.

FIG.3 is list of DL signaling information to support non-transparent MU-MIMO according to another embodiment.

Referring to FIG.3, in order to support non-transparent MU-MIMO 100, the information on non-transparent MU-MIMO included in coded control information by the channel encoder 210 comprises only total rank of the base station 110, and the specific scheduled terminal' s rank and antenna ports information. In other words, in non-transparent MU-MIMO 100, only total rank of the base station 110 and the specific scheduled terminal' s rank and antenna ports information are transmitted by the DL signaling. Based on this DL signaling,

each terminal 120 to 140 included in the MU-MIMO 100 knows total rank of the base station 110 and its own information. Antenna ports information refers to an index of layer for specific terminal.

For terminal's perspective, each of terminals 120 to 140 knows the total interference information based on the total rank and its own information. In this case, each terminal 120 to 140 may be informed of which DM-RS pattern is being used. DM-RS pattern is described below in detail as shown in FIG.

It is good for the interference mitigation at the terminal side. So it can also have better performance than the transparent MU-MIMO. The overhead is greatly reduced.

The total rank of the base station 110 is less than or equal to each terminal rank. If the total rank is higher than the rank of the terminal, it can be known that the wireless communication system is MU-MIMO. If the total rank is the same as the rank of the rank of the terminal, it can be known that the wireless communication system is SU-MIMO.

Although it is not shown in figure, the information on non-transparent MU-MIMO 100 included in the control information in order to support non-transparent MU-MIMO 100 may comprise all the scheduled terminals' information such as number of scheduled terminals, rank of each terminal and antenna ports of each terminals, which are transmitted to all the scheduled terminals.

The scrambler 220 scrambles coded bits in each of the codewords to be transmitted on a physical channel.

The modulation mapper 230 modulates scrambled bits to generate complex-valued modulation symbols.

The layer mapper 240 maps the complex-valued modulation symbols onto one or several transmission layers.

The precoder 250 precodes the complex-valued modulation symbols on each layer for transmission on the antenna ports. The precoder 250 precodes data and control information($\bar{d}_1$ and $\bar{d}_2$) by means of each of precoding matrices(C_1 and C_2).

The resource element mapper 260 maps complex-valued modulation symbols for each antenna port to resource elements.

The RS related apparatus 270 generally generate a downlink reference signal(RS) such as DM-RS(demodulation reference signal) and provides the generated the reference signal with resource element mapper 260 to perform allocation function into time-frequency resource.

DM-RS may be used in order to transfer the precoding matrix C_i from the base station 110 to the terminals 120 to 140 in the MIMO wireless communication system 100. The terminals 120 to 140 can recover the

information $\bar{d}_i$ for its own data when it know the precoding matrix C_i .

If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission, and use the appropriate DM-RS port for channel estimation and demodulation.

FIG. 4 is a pattern of DM-RS in the resource block for rank 2 and 4.

Referring to FIG.4, DM-RS is allocated into the resource blocks with special DM-RS pattern.

The top view of FIG.4 shows special DM-RS pattern for rank 2 with two transmission layers. In DM-RS pattern for rank 2, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block with different walsh code.

The bottom view of FIG.4 shows special DM-RS pattern for rank 4 with four transmission layers. In DM-RS pattern for rank 4, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 2 and 3 are repeatedly allocated into another same 12 REs of each resource block.

If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission based on the

information for non-transparent MU-MIMO as shown in FIG.3 and table 1. Based on the DM-RS pattern as shown in FIG.4, each of the terminals 120 to 140 can know its own precoding matrix C_i from the base station 110 and then can recover the information $\bar{d}_i$ for its own data when it know the precoding matrix C_i .

FIG.5 is the diagram of a RS resource allocator and a RS generator of the RS-related apparatus 270 in FIG.3 according to another embodiment.

Referring to FIG.2 and FIG.5, the RS related apparatus 270 may comprise a RS generator 510 and a RS resource allocator 520.

The RS generator 510 generates the downlink DM-RS(demodulation reference signal). The RS resource allocator 520 provides the generated the downlink DM-RS with resource element mapper 260 to perform allocation function into time-frequency resource with special DM-RS pattern as shown in FIG.4.

If the total rank and it' s own rank and the number of antenna ports is known at each of the terminals 120 to 140, each of the terminals 120 to 140 can know its own precoding matrix C_i from the base station 110 and then can recover the information $\bar{d}_i$ for its own data when it know the precoding matrix C_i based on the DM-RS pattern as shown in FIG.4. It will be described below that each of the terminals 120 to 140 cancels the

interference and recovers the information $\bar{d}_i$ for its own data by using the total rank, specific terminal's own rank and antenna port and DM-RS pattern, referring to FIG.8.

Referring to FIG.2 again, the OFDM signal generator 280 generates complex-valued time-domain OFDM signal for each antenna port.

Although the base station 200 in non-transparent MIMO communication system 100 is described above, a method for DL control signaling of non-transparent MU-MIMO is described below.

FIG.6 is the flowchart of a method for DL control signaling of non-transparent MU-MIMO according to another embodiment.

Referring to FIG.6, a method for DL control signaling of non-transparent MU-MIMO according to another embodiment 600 signals control information including information on non-transparent MU-MIMO at S620. Of course, the control information includes general information on downlink scheduling assignments, uplink scheduling grants and power control commands as well as information for non-transparent MU-MIMO. The control information including the information for non-transparent MU-MIMO may be transmitted from the base station to the terminal via a control channel, for example PDCCH(Physical Downlink Control Channel). The specific DCI format may contain the control information including the information for non-transparent MU-MIMO.

In this specification signaling the control information means either generating the control information or generating and sending the control information.

In order to support non-transparent MU-MIMO 100, the information on non-transparent MU-MIMO included in the control information may comprise only total rank of the base station 110, and the specific scheduled terminal's rank and antenna ports information as shown in FIG.3 and table 1. In non-transparent MU-MIMO 100, only total rank of the base station 110 and the specific scheduled terminal's rank and antenna ports information are transmitted by the DL signaling.

Although it is not shown in figure, the information on non-transparent MU-MIMO 100 included in the control information in order to support non-transparent MU-MIMO 100 may comprise all the scheduled terminals' information such as number of scheduled terminals, rank of each terminal and antenna ports of each terminals, which are transmitted to all the scheduled terminals.

Next, the downlink DM-RS(demodulation reference signal) is generated and patterned into time-frequency resource with special DM-RS pattern as shown in FIG.4 at S620.

DM-RS may be used in order to transfer the precoding matrix C_i from the

base station 110 to the terminals 120 to 140 in the MIMO wireless communication system 100. The terminals 120 to 140 can recover the information $\bar{d}_i$ for its own data when it know the precoding matrix C_i .

For example, in DM-RS pattern for rank 2, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block. In DM-RS pattern for rank 4, DM-RSs of layers 0 and 1 are repeatedly allocated into the same 12 REs(Resource elements) of each resource block and DM-RSs of layers 2 and 3 are repeatedly allocated into another same 12 REs of each resource block.

If the base station 110 configures the MU-MIMO transmission to at least two terminals 120 and 130, each with a different layer, each terminal must also know on which layer it is going to receive the transmission based on the information on non-transparent MU-MIMO as shown in FIG.3 and table 1. Based on the DM-RS pattern as shown in FIG.4, each of the terminals 120 to 140 can know its own precoding matrix C_i from the base station 110 and then can recover the information $\bar{d}_i$ for its own data when it know the precoding matrix C_i .

Finally, signaled information and patterned DM-RSs are transferred from the base station 110 to the terminals 120 to 140 in form of complex-valued time-

domain OFDM signal for each antenna port at S630.

It is assumed that there is total rank 5 at the base station 110 as an example. It is assumed that the terminal (UE1) is in rank 2 with antenna port 1 and 2, the terminal 2(UE2) is in rank 2 with antenna port 3 and 4, and the terminal 3(UE3) is in rank 1 with antenna 5. The information on non-transparent MU-MIMO for the terminals is shown in the table 1.

【Table 1】

UE ID	1	2	3
Total Rank	5 (3bits)	5 (3bits)	5 (3bits)
Rank and Antenna ports	11000 (5bits)	00110 (5 bit)	00001 (5 bit)

Based on the DL signaling of table 1, the DMRS pattern information at the terminals is described in table 2. DM-RS pattern information at the terminals are described in tables 3 to 5.

【Table 2】

UE1	UE1
UE2	UE2
UE3	Not used
Not used	Not used

【Table 3】

UE1	UE1
Interference	interference
interference	Not used
Not used	Not used

【Table 4】

Interference	Interference
UE2	UE2
Interference	Not used
Not used	Not used

【Table 5】

Interference	Interference
Interference	Interference
UE3	Not used
Not used	Not used

FIG.7 is the block diagram of a terminal according to another embodiment.

Referring to FIG.7, a terminal according to another embodiment 700 comprises a RF receiver 710, a decoder 720 and a controller 730.

The RF receiver 710 receives complex-valued time-domain OFDM signal for each antenna port from the base station.

The decoder 720 decodes the received complex-valued time-domain OFDM signal into the original information such as the data and the control information. The decoded information includes the signaled information on non-transparent MU-MIMO as shown in FIG.3 and patterned DM-RSs as shown in FIG.4 from the base station 110 to the terminals 120 to 140.

The controller 730 is configured to control interference cancellation using the signaled information and patterned DM-RSs.

The interference cancellation using the signaled information and patterned DM-RSs is described below referring to FIG.8.

FIG.8 is the flowchart of a method for operating received control signal and DM-RS in MU-MIMO wireless communication system.

In the method for operating received control signal and DM-RS 600 in MU-MIMO wireless communication system, the terminal 700 receives the signaled information as shown in FIG.3 and patterned DM-RSs as shown in FIG.4 from the base station 110 to the terminals 120 to 140 by means of complex-valued time-domain OFDM signal for each antenna port as S810.

Next, the terminal 700 separate its own data from all the data by means of interference cancellation technique at S820.

The terminal 700 can know the total rank and its own rank and the number of antenna ports from signaled information on non-transparent MU-MIMO.

It will be described below that each of the terminals 120 to 140 cancels the interference and recovers the information $\bar{d}_i$ for its own data by using the total rank, specific terminal' s own rank and antenna port as well as DM-RS pattern at terminal' s perspective.

If it is assumed that rank of the DM-RS is R_{DMRS} and total rank is

R_{total} , the RDMRS can be got from R_{total} by $R_{DMRS} \in \{1, 2, 4, 8\}$ where

$$R_{DMRS} \geq R_{total} \text{ and } 2R_{total} > R_{DMRS}.$$

There is the relation between DMRS pattern rank and the total rank by the following table 6.

【Table 6】

Total Rank	1	2	3	4	5	6	7	8
DM-RS Rank	1	2	4	8				

At the terminal side, if the total rank is higher than the rank of the terminal 700, the terminal 700 can know it is in MU-MIMO. If the total rank is the same as the rank of the terminal 700, the terminal 700 can know it is in SU-MIMO. If it is assumed that the rank of the terminal i is R_i , then the following expression is derived.

If $R_{total} = R_i$ SU-MIMO and If $R_{total} > R_i$ MU-MIMO

If the terminal 700 is in MU-MIMO, the rank of the interference is the total rank minus this terminal's own rank. If it is assumed that total interference rank is $R_{interference}$ for the terminal i and the number of the terminal 700 in MU-MIMO is N , then the following expression is derived.

$$R_{interference} = \sum_{\substack{j=1 \\ j \neq i}}^N R_j = R_{total} - R_i$$

If it is assumed that the number of Tx antennas at the base station 110 is N_t and the number of Rx antennas is N_r at the terminal i , the

received signal can be expressed as follows.

$$Y = H C_i X_i + \sum_{\substack{j=1 \\ j \neq i}}^N H C_j X_j + n = \tilde{H}_i X_i + \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{H}_j X_j + n$$

where H is $N_r \times N_t$ channel matrix at the terminal i and C_i is the $N_t \times R_i$ precoding matrix for the terminal i . Moreover, n is the noise at the terminal. If we use $\tilde{H}_i = H C_i$ to express the $N_t \times R_i$ precoding channel, the received signal can be express as

$$Y = \tilde{H}_i X_i + \sum_{\substack{j=1 \\ j \neq i}}^N \tilde{H}_j X_j + n$$

As known in the above expression, the channel matrix H can be known from the well-known downlink channel estimation. Because each terminal 700 included in the MU-MIMO 100 can also know the antenna ports information of orthogonal DMRS based on this DL signaling, the precoding matrix C_i for the terminal i can be known from its own antenna ports information of orthogonal DMRS.

Based on the DMRS pattern, his antenna ports and total rank, the antenna port of all the interference can also be known even if the terminal 700 do not know the interference of which terminals is derived.

So the terminal 700 can estimate both its own precoded channel $\tilde{\mathbf{H}}_i$ and the channel of the interference $\tilde{\mathbf{H}}_j$ $j=1, \dots, N$ and $j \neq i$.

If the number of received antenna N_r is larger than R_{total} , the terminal 700 can perfectly remove the interference from all the other terminals in theory once the terminal knows its own precoded channel $\tilde{\mathbf{H}}_i$ and the channel of the interference $\tilde{\mathbf{H}}_j$ $j=1, \dots, N$ and $j \neq i$. That is, if $N_r \geq R_{total}$, we can find the weight matrix $\mathbf{W}_i$ to make $\mathbf{W}_i \tilde{\mathbf{H}}_i = \mathbf{I}$ and $\mathbf{W}_i \tilde{\mathbf{H}}_j = \mathbf{0}$ ($j=1, \dots, N$ and $j \neq i$). This $\mathbf{W}_i$ can be got by zero forcing as follows:

$$\mathbf{W}_i = (\tilde{\mathbf{H}}^{-1})_i$$

Where $\tilde{\mathbf{H}} = [\tilde{\mathbf{H}}_1, \tilde{\mathbf{H}}_2, \dots, \tilde{\mathbf{H}}_N]$. The terminal i can get its own data symbols as follows:

$$\begin{aligned} \hat{\mathbf{X}}_i &= \mathbf{W}_i \mathbf{Y} = \mathbf{W}_i \tilde{\mathbf{H}}_i \mathbf{X}_i + \sum_{\substack{j=1 \\ j \neq i}}^N \mathbf{W}_i \tilde{\mathbf{H}}_j \mathbf{X}_j + \mathbf{W}_i \mathbf{n} \\ &= \mathbf{X}_i + \mathbf{W}_i \mathbf{n} \end{aligned}$$

As described above, it can be seen that all the interferences from other terminals are perfectly removed. So it can also have better performance

than the non-transparent MU-MIMO.

Moreover $\mathbf{w}_i$ can also be got by MMSE as follows to reduce the effect of the noise $\mathbf{n}$:

$$\mathbf{W}_i = ((\tilde{\mathbf{H}}^H \tilde{\mathbf{H}} + \sigma^2 \mathbf{I})^{-1} \tilde{\mathbf{H}}^H)_i$$

where σ^2 is the variance of the noise. The $\mathbf{w}_i$ by MMSE can make the non-transparent MU-MIMO have much better performance than the zero forcing detection. It is the optimal linear detection for the non-transparent MU-MIMO.

In proposed scheme, only total rank of the base station and the specific scheduled terminal' s rank and antenna ports information are transmitted by the DL signaling. If the total rank is higher than the rank of UE, the UE can know he is in MU-MIMO. If the total rank is the same as the rank of UE, the UE can know he is in SU-MIMO. If the UE is in MU-MIMO, the rank of the interference is the total rank minus this terminal' s own rank. If the number of received antenna is larger than R_{total} , He can perfectly remove the interference from all the other terminals in theory. It is good for the interference mitigation at the terminal side. So it can also have better performance than the non-transparent MU-MIMO. In proposed scheme, only total rank of the base station and the specific

scheduled terminal's rank and antenna ports information are transmitted by the DL signaling, so that the overhead is reduced.

The methods and systems as shown and described herein may be implemented in software stored on a computer-readable medium and executed as a computer program on a general purpose or special purpose computer to perform certain tasks. For a hardware implementation, the elements used to perform various signal processing steps at the transmitter(e.g., coding and modulating the data, precoding the modulated signals, preconditioning the precoded signals, and so on) and/or at the receiver(e.g., recovering the transmitted signals, demodulating and decoding the recovered signals, and so on) may be implemented within one or more application specific integrated circuits(ASICs), digital signal processors(DSPs), digital signal processing devices (DSPDs), programmable logic devices(PLDs), field programmable gate arrays(FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. In addition or in the alternative, a software implementation may be used, whereby some or all of the signal processing steps at each of the transmitter and receiver may be implemented with modules(e.g., procedures, functions, and so on) that perform the

functions described herein. It will be appreciated that the separation of functionality into modules is for illustrative purposes, and alternative embodiments may merge the functionality of multiple software modules into a single module or may impose an alternate decomposition of functionality of modules. In any software implementation, the software code may be executed by a processor or controller, with the code and any underlying or processed data being stored in any machine-readable or computer-readable storage medium, such as an on-board or external memory unit.

Although the described exemplary embodiments disclosed herein are directed to various MIMO precoding systems and methods for using same, the present invention is not necessarily limited to the example embodiments illustrate herein. For example, various embodiments of a MIMO precoding system and design methodology disclosed herein may be implemented in connection with various proprietary or wireless communication standards, such as IEEE 802.16e, 3GPP-LTE, DVB and other multi-user MIMO systems. Thus, the particular embodiments disclosed above are illustrative only and should not be taken as limitations upon the present invention, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Accordingly, the foregoing

description is not intended to limit the invention to the particular form set forth, but on the contrary, is intended to cover such alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims so that those skilled in the art should understand that they can make various changes, substitutions and alterations without departing from the spirit and scope of the invention in its broadest form.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element of any or all the claims. As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

【CLAIMS】**【Claim 1】**

A base station in the multi-user Multiple-Input Multiple-Output (MU-MIMO), comprising:

a layer mapper mapping a codeword to the layers and generating the information for non-transparent MU-MIMO;

a precoder precoding a mapped set of symbols using a precoding matrix;

a resource element mapper mapping a precoded set of symbols for each antenna port to resource elements; and

an OFDM signal generator generating an OFDM signal which includes downlink control signaling for each antenna port to specific terminal among all the terminals.

【Claim 2】

The base station in claim 1, wherein the information on the non-transparent MU-MIMO comprises the total rank and specific terminal's own information.

【Claim 3】

The base station in claim 1, further comprises a RS-related generator generating a downlink DM-RS(demodulation reference signal) and providing the generated the reference signal with resource element mapper.

【Claim 4】

The base station in claim 1, wherein the RS-related generator patterns the downlink MS-RS in order to support the non-transparent MU-MIMO.

【Claim 5】

A method in the multi-user Multiple-Input Multiple-Output(MU-MIMO), comprising:

Generating an information on non-transparent MU-MIMO;

generating an information related to DM-RS; and

sending for the non-transparent MU-MIMO and the information related to DM-RS.

【Claim 6】

The method in claim 5, wherein the information on the non-transparent MU-MIMO comprises the total rank and specific terminal's own information including the rank and the antenna ports of this terminal.

【Claim 7】

The method in claim 5, wherein the information related to DM-RS is the downlink DS-RS pattern.

【Claim 8】

A terminal in the multi-user Multiple-Input Multiple-Output (MU-MIMO), comprising;

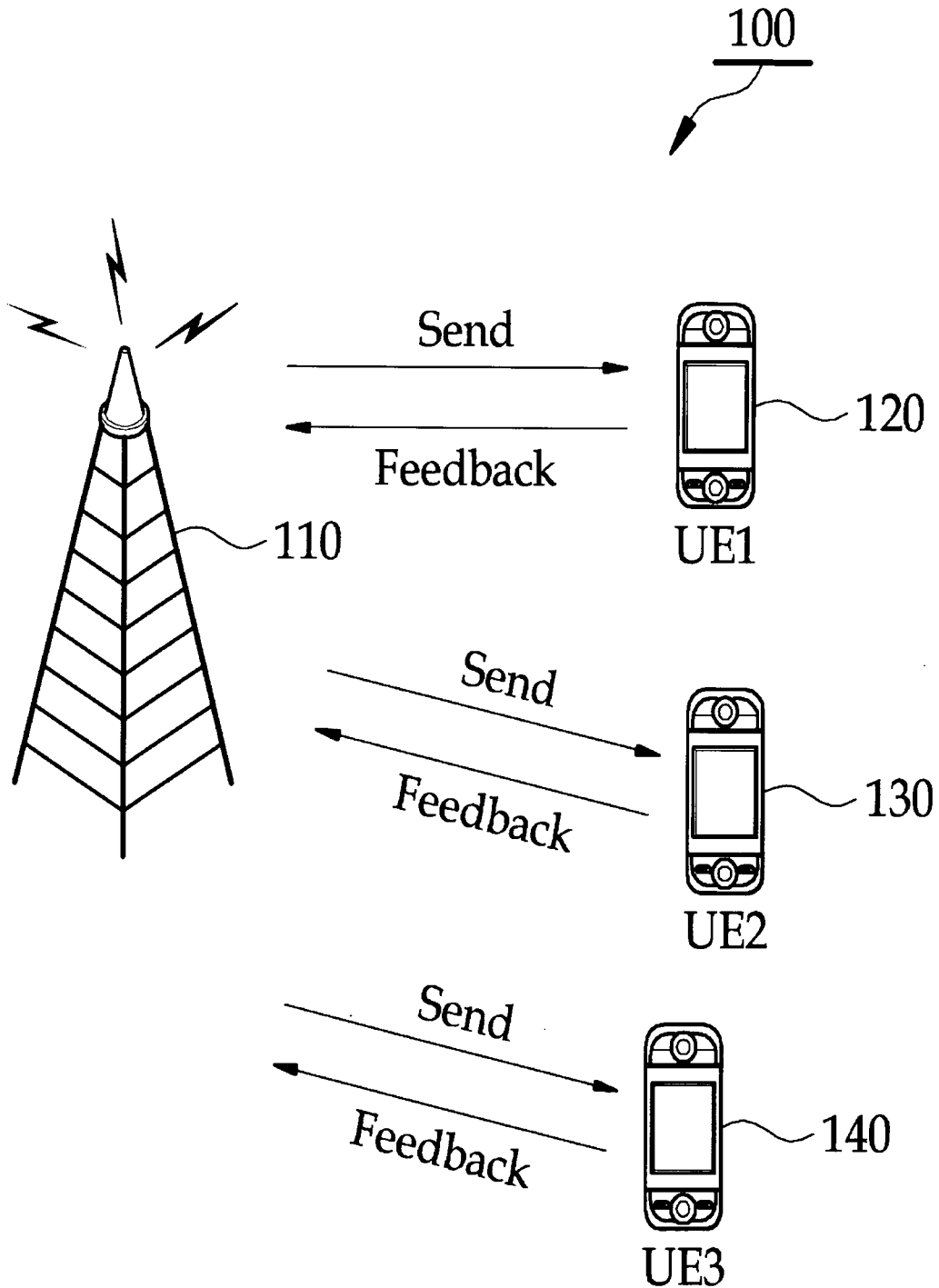
a RF receiver complex-valued time-domain OFDM signal for each antenna port from the base station;

a decoder decoding the received complex-valued time-domain OFDM signal into the original information where the decoded information includes the signaled information on non-transparent MU-MIMO and patterned DM-RSs from the base station; and

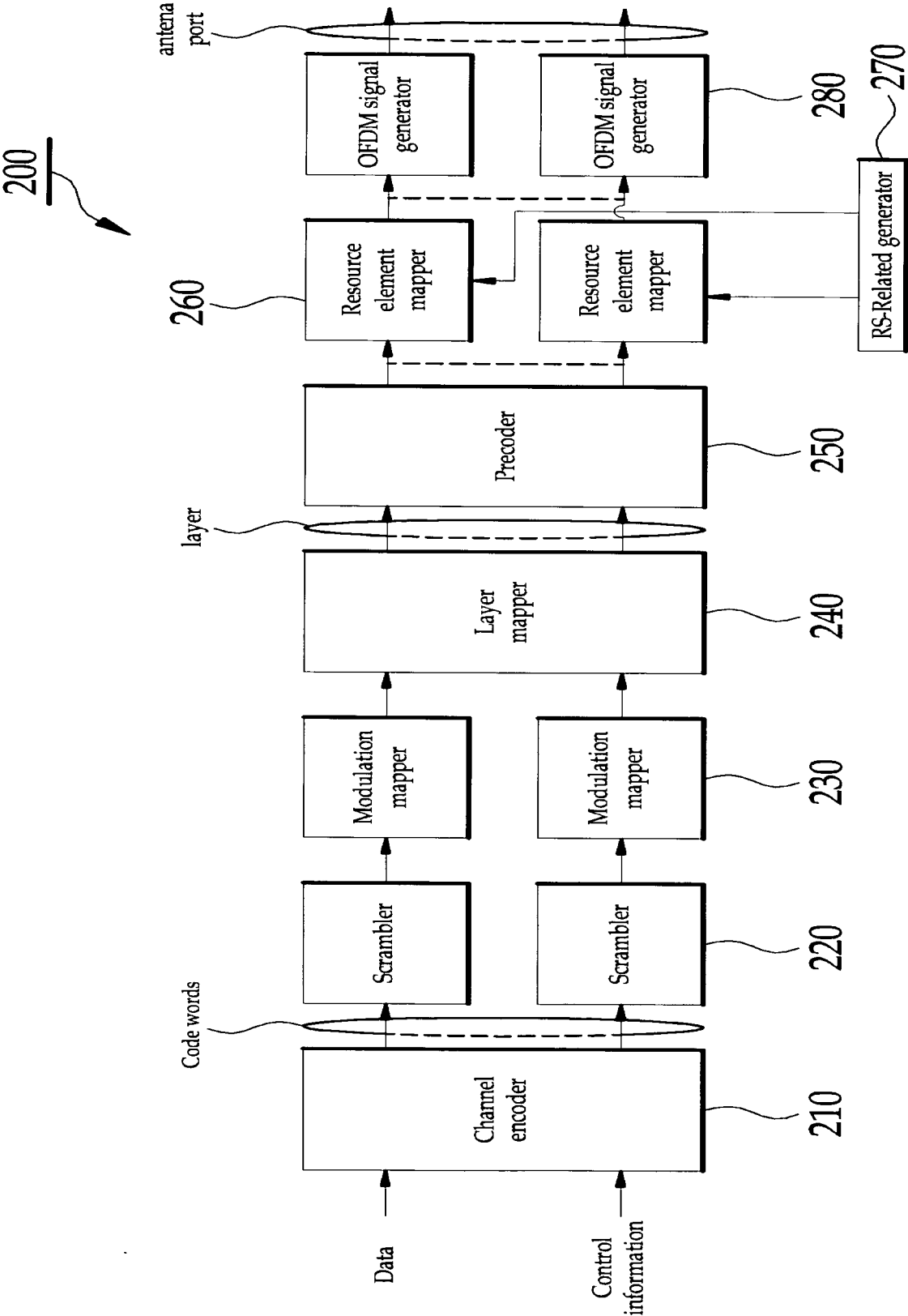
a controller configured to control interference cancellation using the signaled information and patterned DM-RSs.

【DRAWINGS】

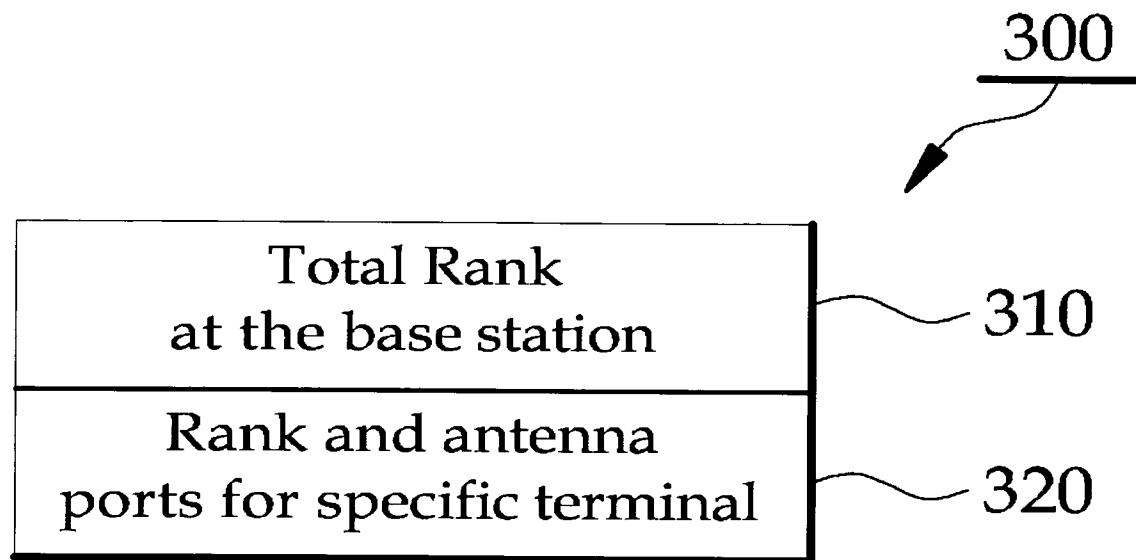
【Figure 1】



【Figure 2】



【Figure 3】



【Figure 4】

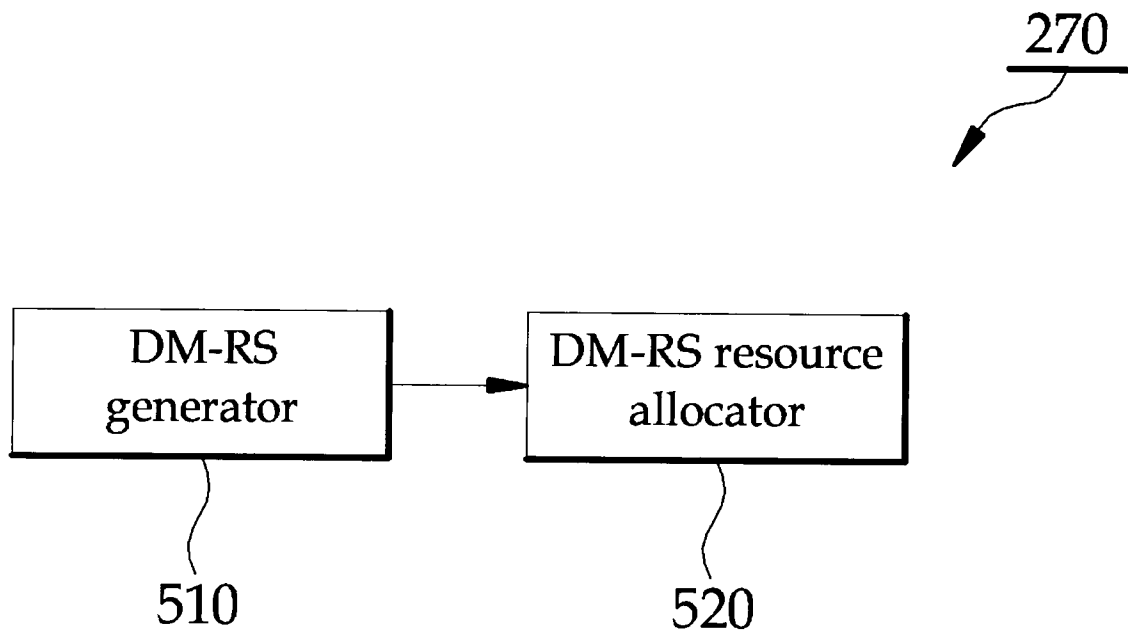
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					0 1	0 1						0 1	0 1
					0 1	0 1						0 1	0 1

rank 2

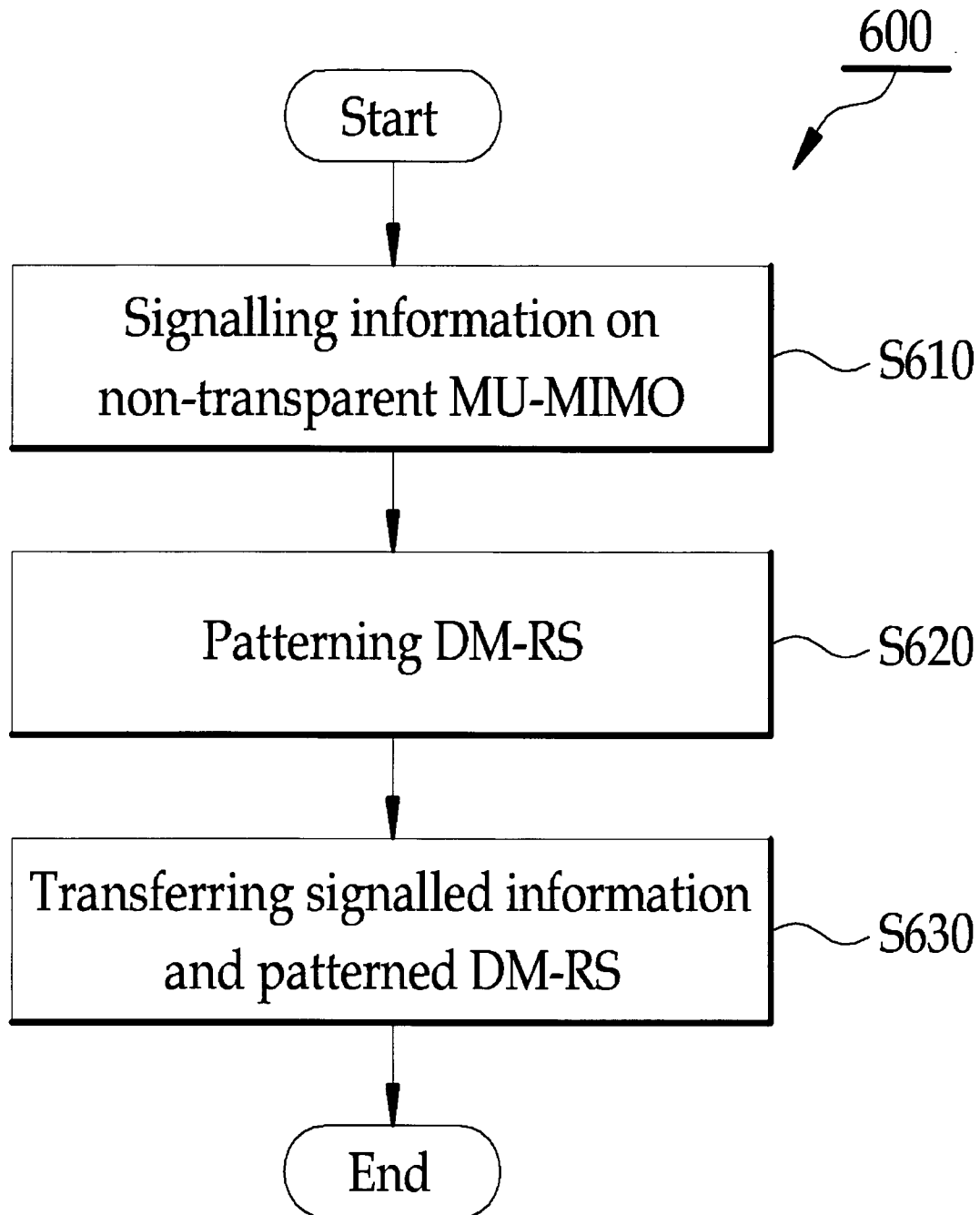
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					0 1	0 1						0 1	0 1
					2 3	2 3						2 3	2 3
					0 1	0 1						0 1	0 1
					2 3	2 3						2 3	2 3

rank 4

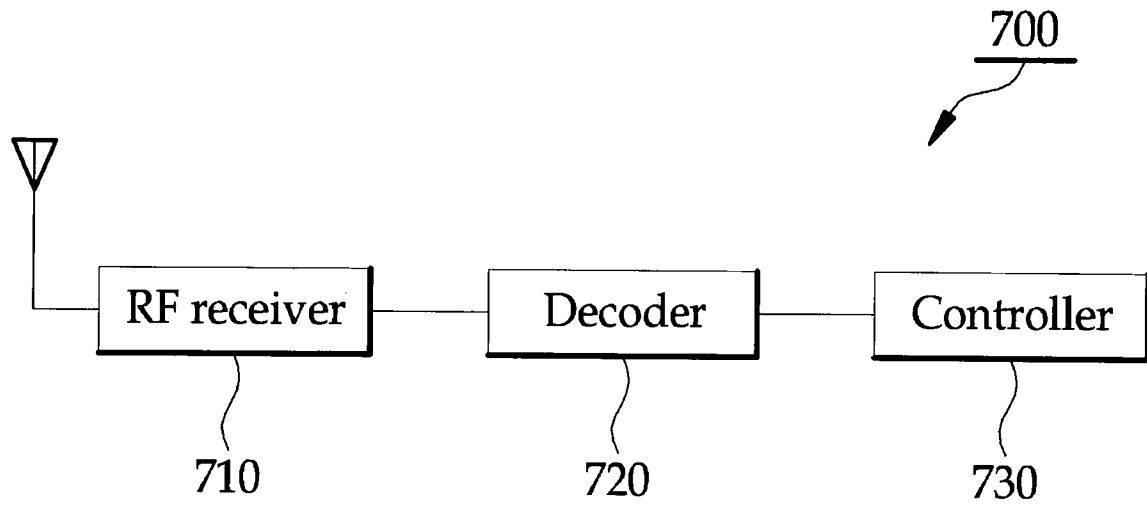
【Figure 5】



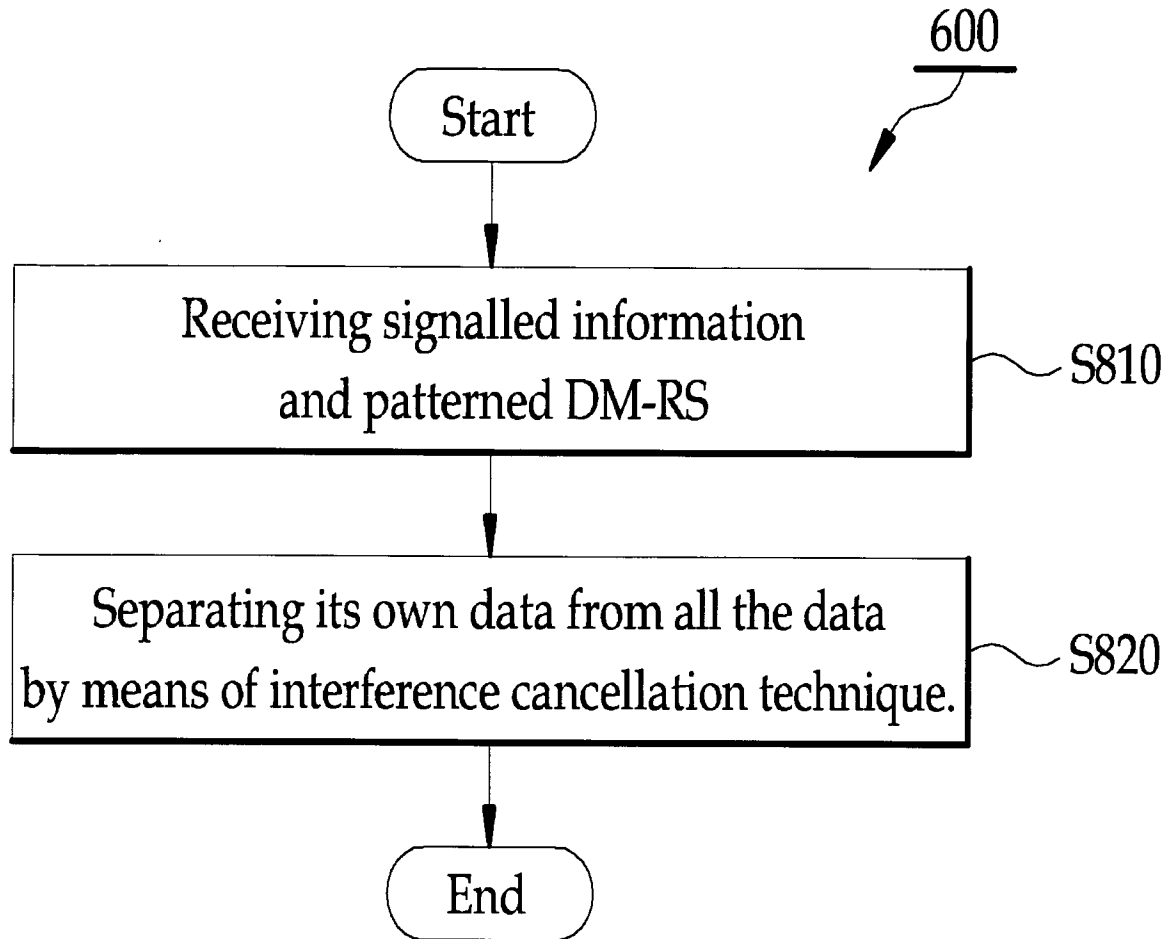
【Figure 6】



【Figure 7】



【Figure 8】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2010/000191**A. CLASSIFICATION OF SUBJECT MATTER****H04J 11/00(2006.01)i, H04B 7/04(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04J 11/00; H04L 27/00; H04L 1/06; H04L 1/02; H04Q 7/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & IEEE xplora

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007-0274409 A1 (JONG-HYEON PARK) 29 November 2007 See page 2 paragraph[0020] - page 6 paragraph[0069]	1-8
A	US 2003-0125040 A1 (JAY R. WALTON et al.) 03 July 2003 See page 2 paragraph[0043] - page 18 paragraph[0266]	1-8
A	US 2007-0223367 A1 (GANG WU, et al.) 27 September 2007 See page 3 paragraph[0035] - page 8 paragraph[0103]	1-2



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

16 SEPTEMBER 2010 (16.09.2010)

Date of mailing of the international search report

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JANG, Dae Geun

Telephone No. 82-42-481-5710



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2010/000191

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0274409 A1	29.11.2007	CA 2650633-A1	13.12.2007
		CN 101523761 A	02.09.2009
		EP 2020096 A2	04.02.2009
		JP 2009-538570 A	05.11.2009
		JP 2009-538570 T	05.11.2009
		KR 10-2009-0016487 A	13.02.2009
		WO 2007-142858 A2	13.12.2007
		WO 2007-142858 A3	20.03.2008
		WO 2007-142858 A3	13.12.2007
US 2003-0125040 A1	03.07.2003	BR 0213913 A	26.04.2005
		CN 1613201 A	04.05.2005
		CN 1613201 C0	04.05.2005
		EP 1442538 A1	04.08.2004
		JP 2005-509360 A	07.04.2005
		JP 2005-509360 T	07.04.2005
		KR 10-2005-0043783 A	11.05.2005
		TW 269549 B	21.12.2006
		US 2003-125040 A1	03.07.2003
		US 2006-0121946 A1	08.06.2006
		US 7636573 B2	22.12.2009
		WO 03-041300 A1	15.05.2003
US 2007-0223367 A1	27.09.2007	CN 1691539 A	02.11.2005
		CN 1947371 A	11.04.2007
		CN 1947371 C0	11.04.2007
		EP 1745578 A1	24.01.2007
		JP 2007-535854 A	06.12.2007
		JP 2007-535854 T	06.12.2007
		KR 10-2007-0007159 A	12.01.2007
		US 2007-223367 A1	27.09.2007
		WO 2005-107125 A1	10.11.2005