US009270428B2

(12) **United States Patent**
Moulsley et al.

(10) **Patent No.: US 9,270,428 B2**
(45) **Date of Patent: *Feb. 23, 2016**

(54) **METHOD FOR SIGNALING A PRECODING IN A COOPERATIVE BEAMFORMING TRANSMISSION MODE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/271,544**

(22) Filed: **May 7, 2014**

(65) **Prior Publication Data**

US 2014/0241291 A1 Aug. 28, 2014

Related U.S. Application Data

(63) Continuation of application No. 14/053,706, filed on Oct. 15, 2013, and a continuation of application No. 12/896,085, filed on Oct. 1, 2010, now Pat. No. 8,634,779.

(30) **Foreign Application Priority Data**

Oct. 5, 2009 (EP) 09172194

(51) **Int. Cl.**

H04W 4/00 (2009.01)
H04L 5/00 (2006.01)
H04B 7/02 (2006.01)
H04B 7/06 (2006.01)

(Continued)

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

CPC ***H04L 5/0035*** (2013.01); ***H04B 7/024*** (2013.01); ***H04B 7/04*** (2013.01); ***H04B 7/0456*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC H04W 4/00
USPC 455/63.1, 450, 422.1, 16, 17, 19, 67.11, 455/67.13, 226.1; 370/329
See application file for complete search history.

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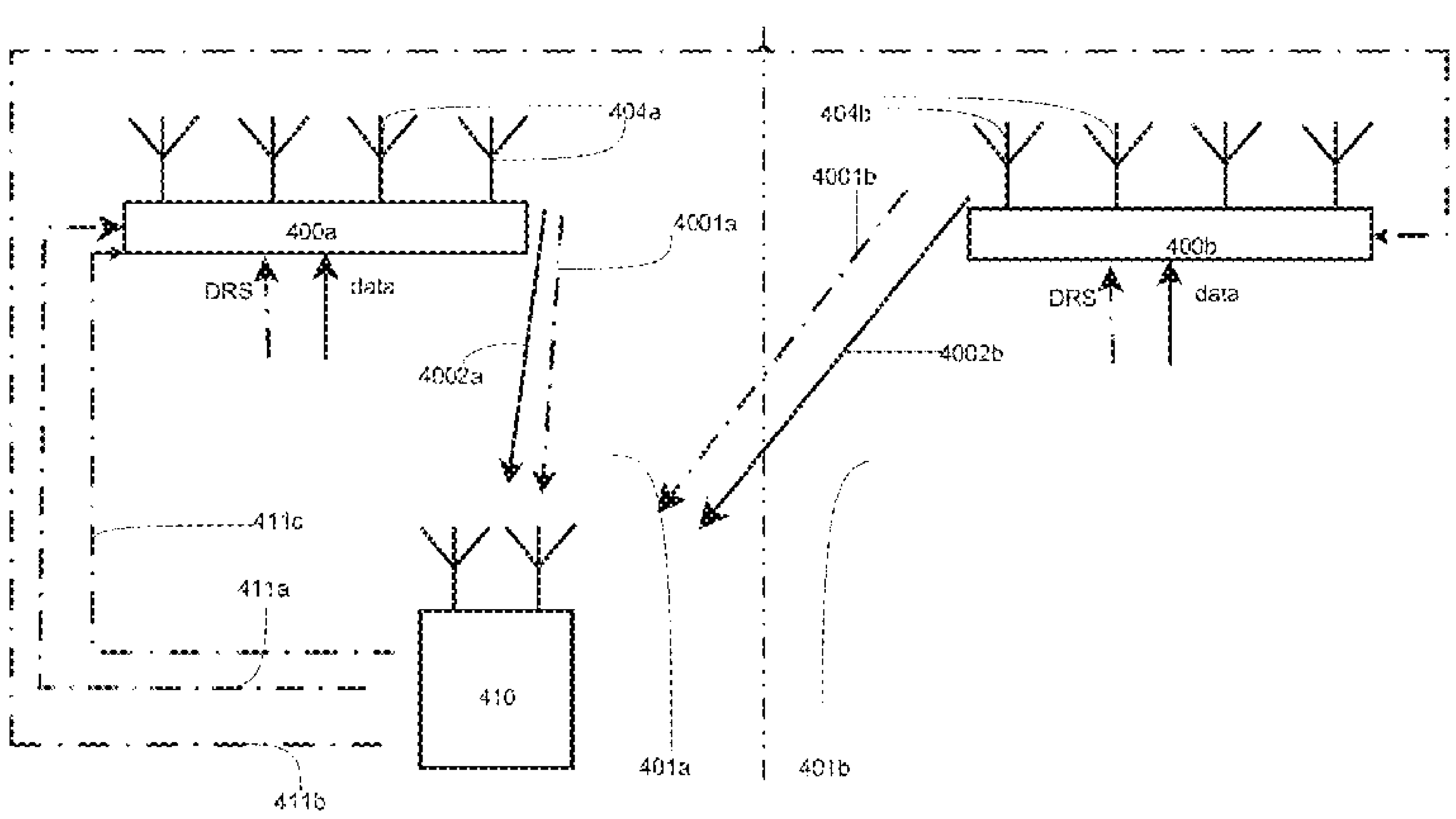
Primary Examiner — Temica M Beamer

(57) **ABSTRACT**

In a method for operating a secondary station in a network, the secondary station: controlling a transceiver configured for simultaneously receiving transmissions from a first primary station controlling a first cell and at least one second primary station controlling a second cell; selecting a first precoding matrix for the first cell out of a first set of precoding matrices for the first cell; selecting, depending on the first precoding matrix, in accordance with a precoding scheme, a subset out of a second set of precoding matrices for the second cell, the subset comprising at least one precoding matrix for the second cell; selecting a second precoding matrix for the at least one second cell out of the selected subset of precoding matrices; transmitting a first and second indicator representative of the respective first and second precoding matrix; wherein the second precoding matrix is based on the value of the first indicator, so that the amount of data used for transmitting the second indicator is less than the amount of data used for transmitting the first indicator.

34 Claims, 10 Drawing Sheets



(51) **Int. Cl.**
H04B 7/04 (2006.01)
H04L 25/03 (2006.01)

(52) **U.S. Cl.**
CPC ***H04B 7/0486*** (2013.01); ***H04B 7/0617*** (2013.01); ***H04B 7/0634*** (2013.01); ***H04B 7/0639*** (2013.01); ***H04B 7/0641*** (2013.01); ***H04L 25/03891*** (2013.01)

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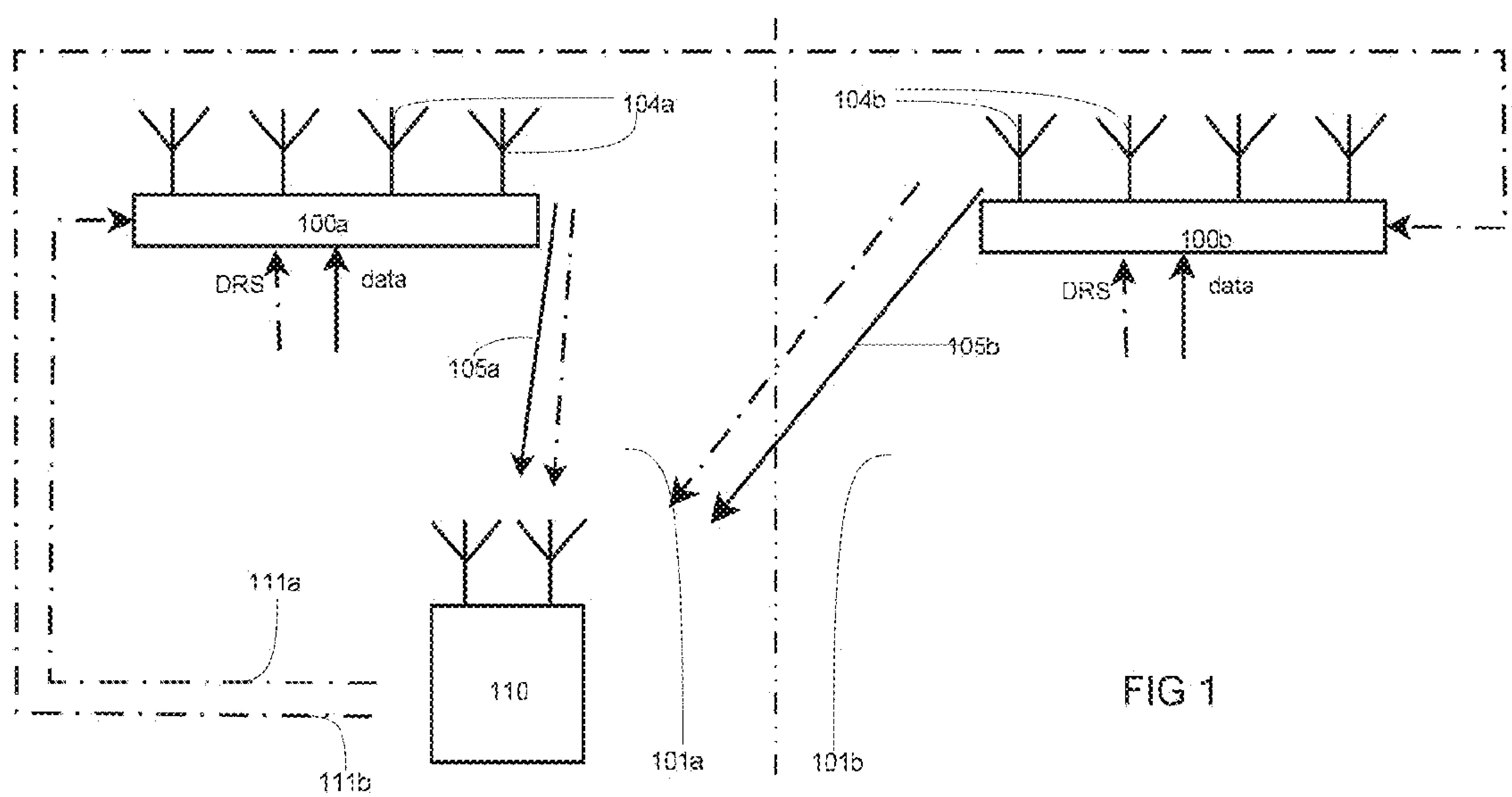

104a
104b
100a
100b
DRS
data
DRS
data
105a
105b
111a
111b
110
101a
101b

FIG 1

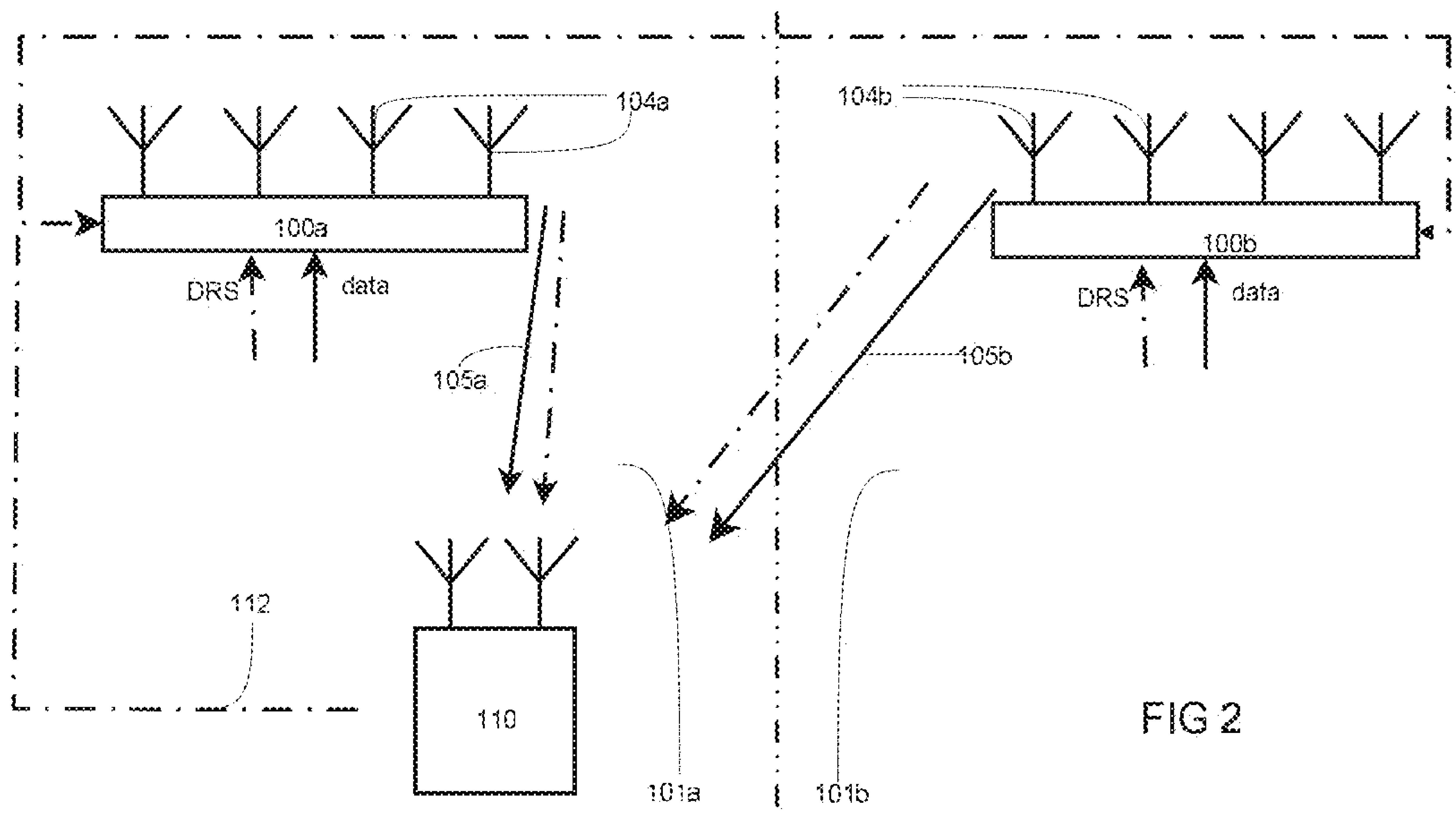

104a
104b
100a
100b
DRS
data
DRS
data
105a
105b
112
110
101a
101b

FIG 2

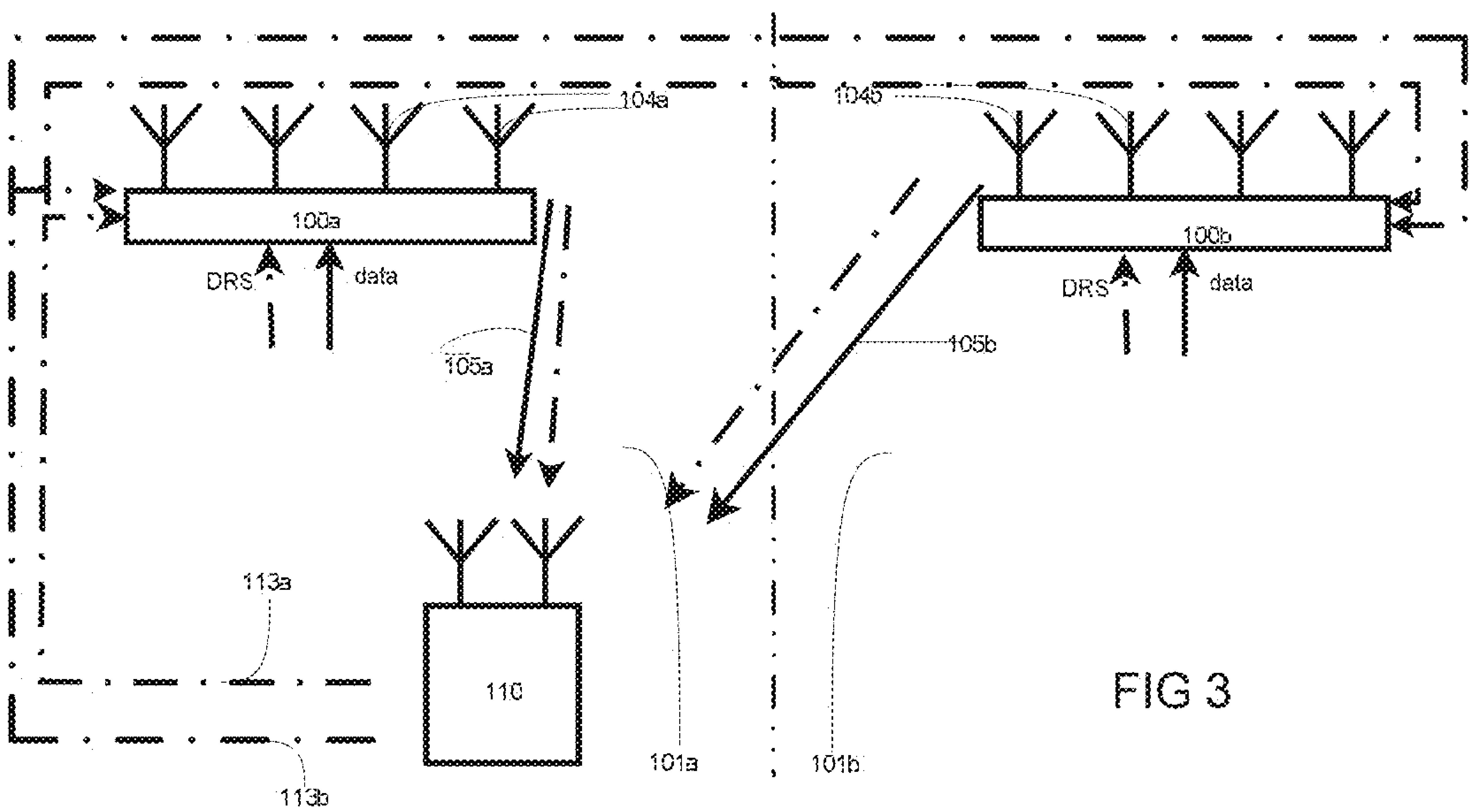
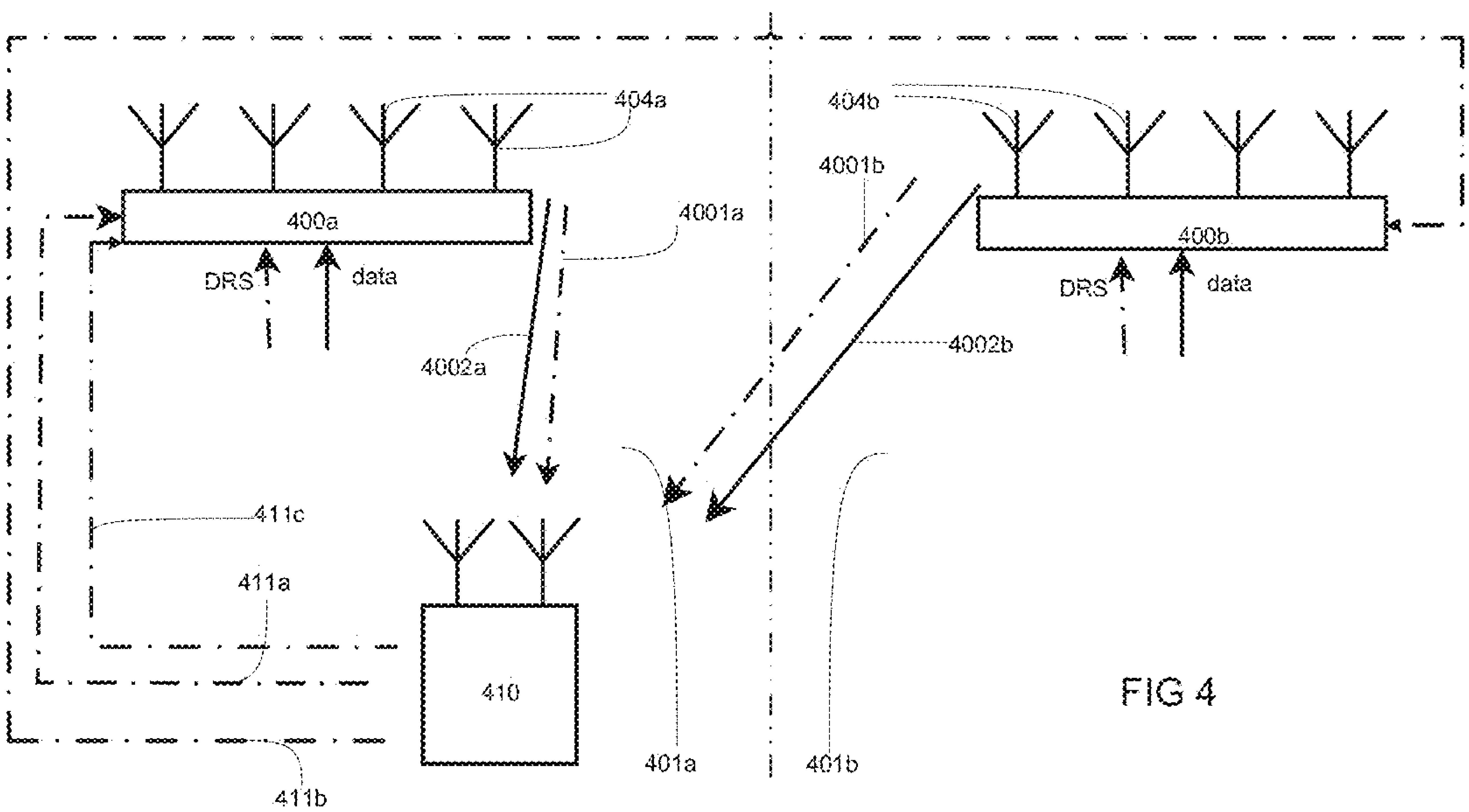

104a
104b
100a
100b
DRS
data
DRS
data
105a
105b
110
113a
113b
101a
101b

FIG 3



404a
404b
4001b
400a
400b
4001a
DRS
data
DRS
data
4002a
4002b
411c
411a
410
401a
401b
411b

FIG 4

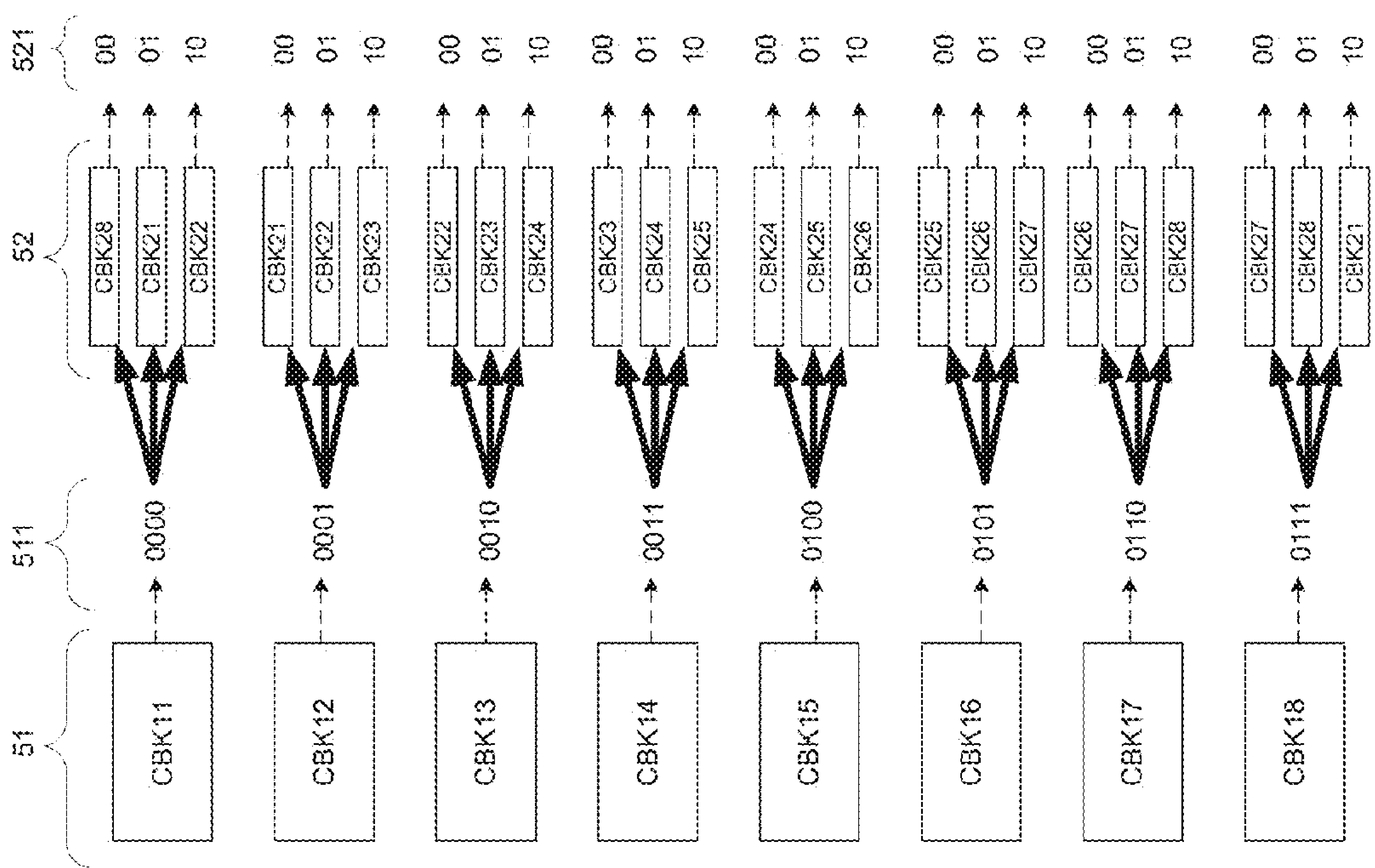

51
511
52
521
CBK11
0000
CBK28
CBK21
CBK22
00
01
10
CBK12
0001
CBK21
CBK22
CBK23
00
01
10
CBK13
0010
CBK22
CBK23
CBK24
00
01
10
CBK14
0011
CBK23
CBK24
CBK25
00
01
10
CBK15
0100
CBK24
CBK25
CBK26
00
01
10
CBK16
0101
CBK25
CBK26
CBK27
00
01
10
CBK17
0110
CBK26
CBK27
CBK28
00
01
10
CBK18
0111
CBK27
CBK28
CBK21
00
01
10

FIG 5

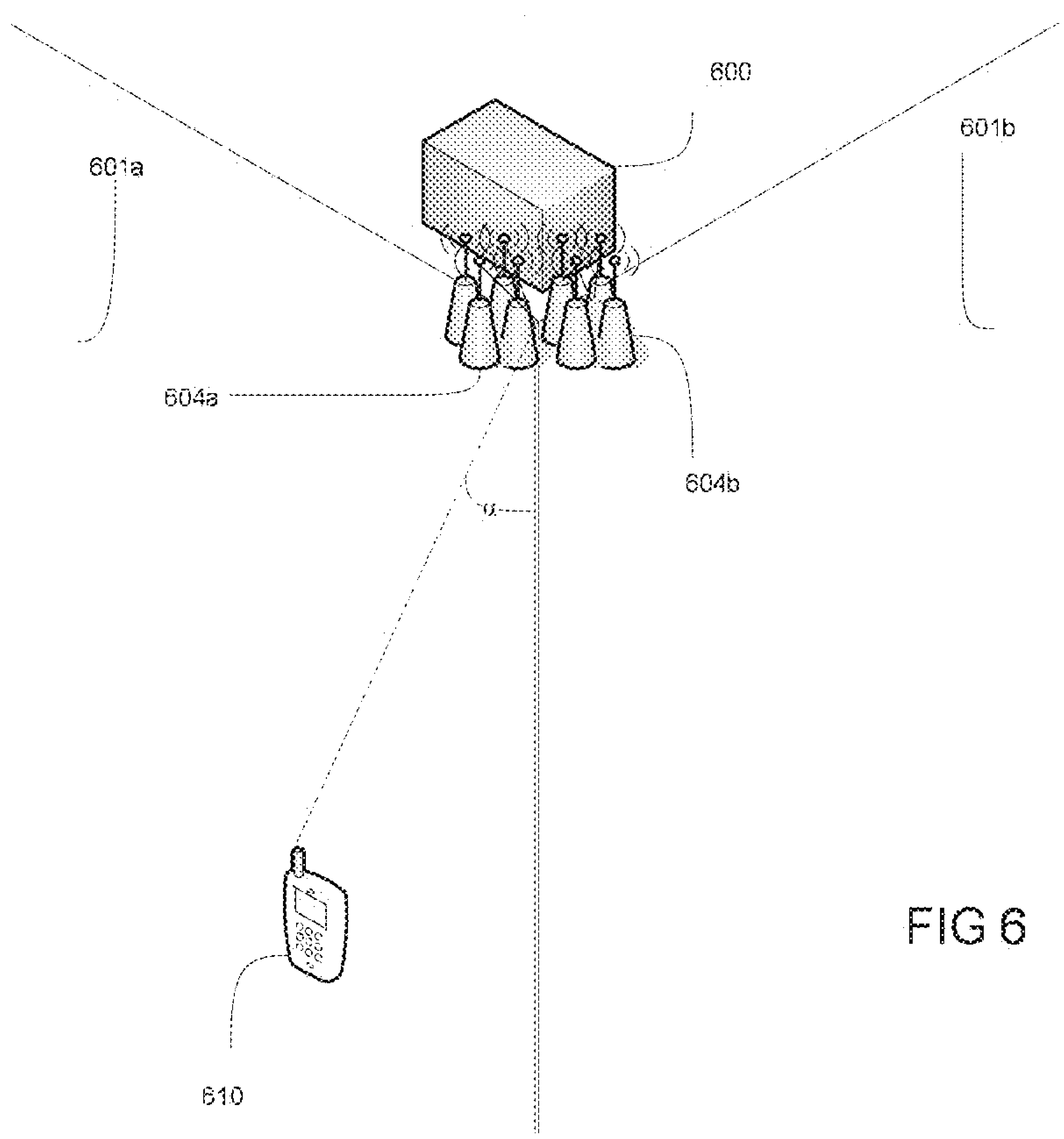


FIG 6

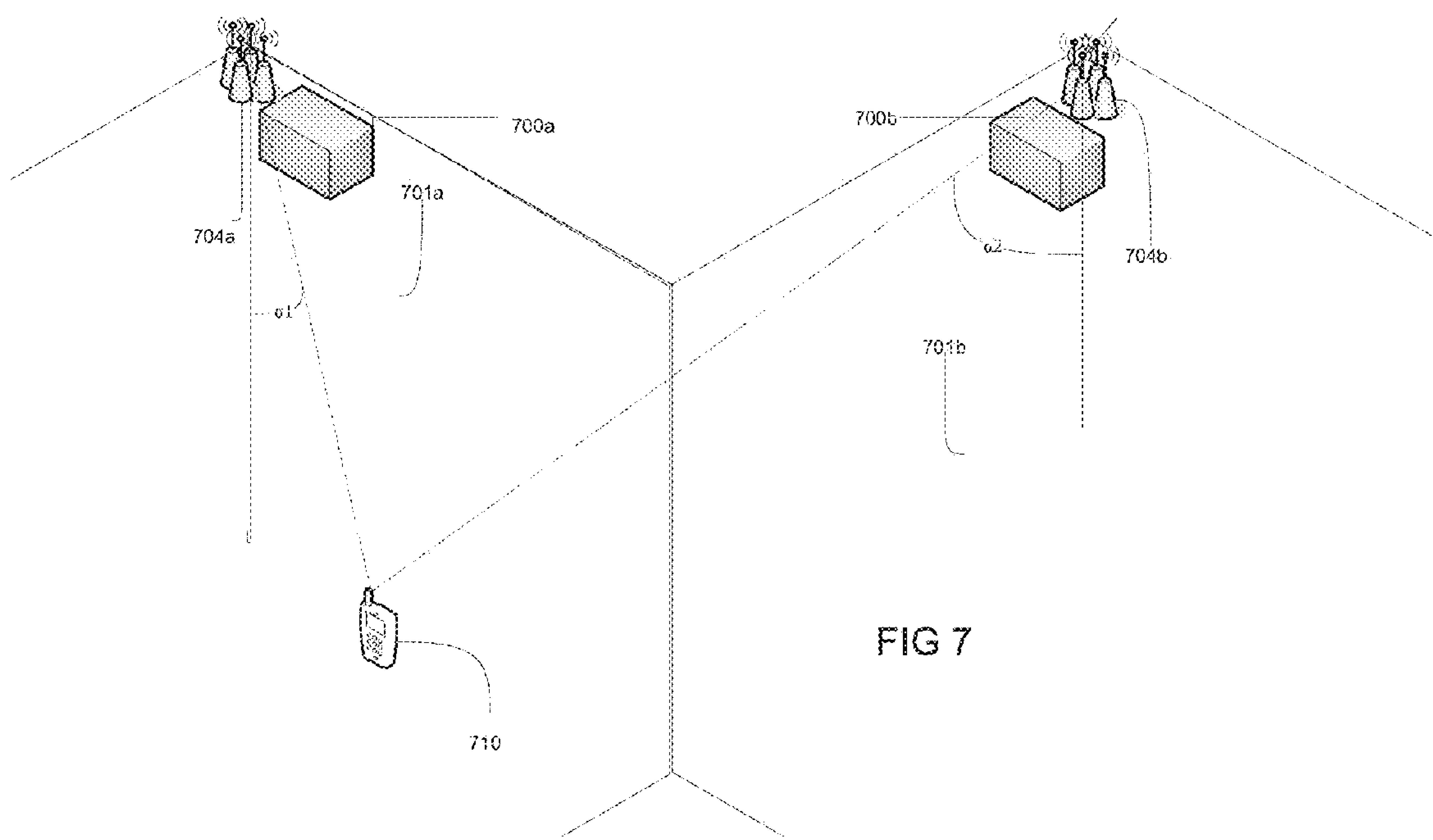


FIG 7

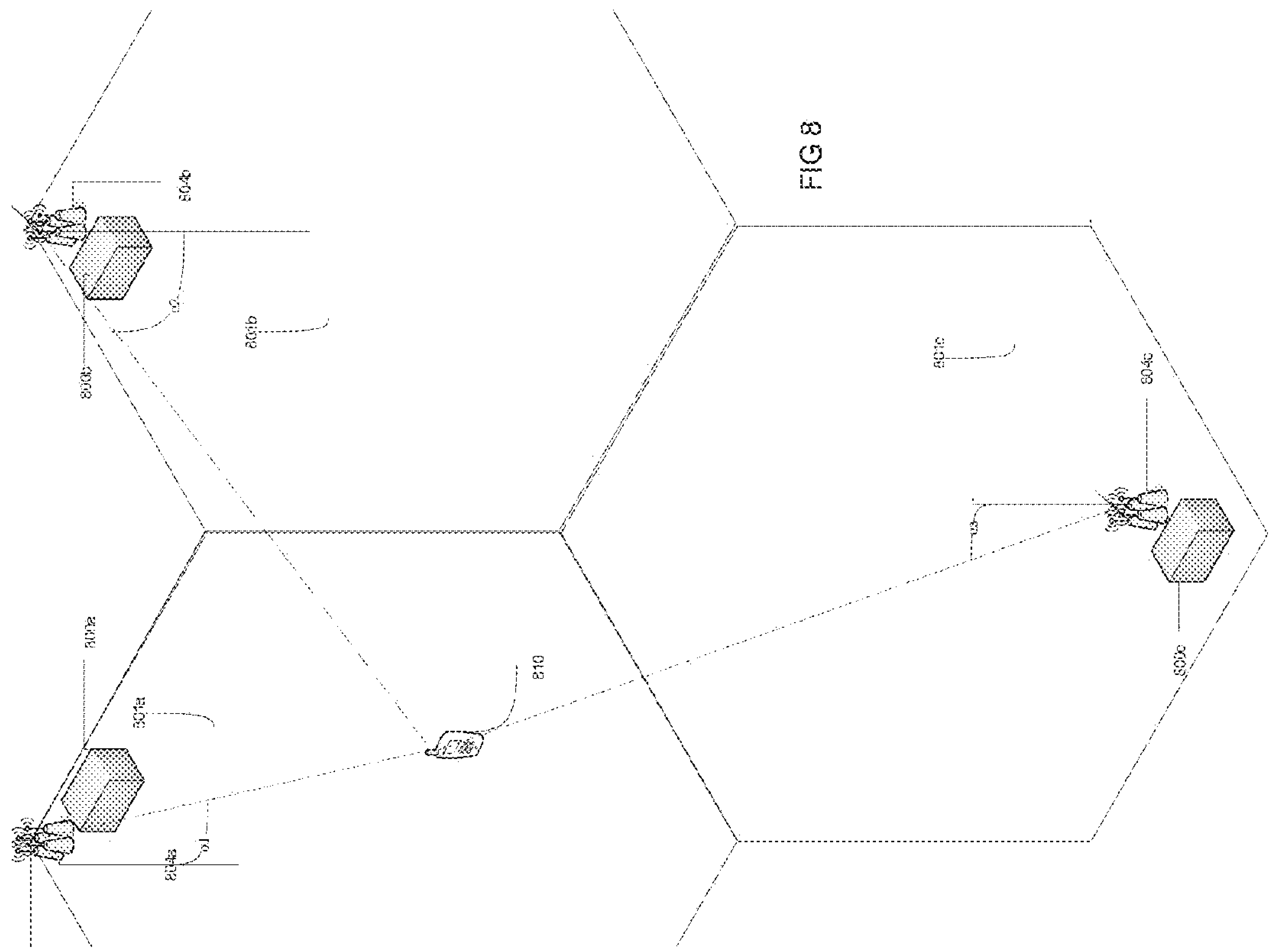


FIG 8

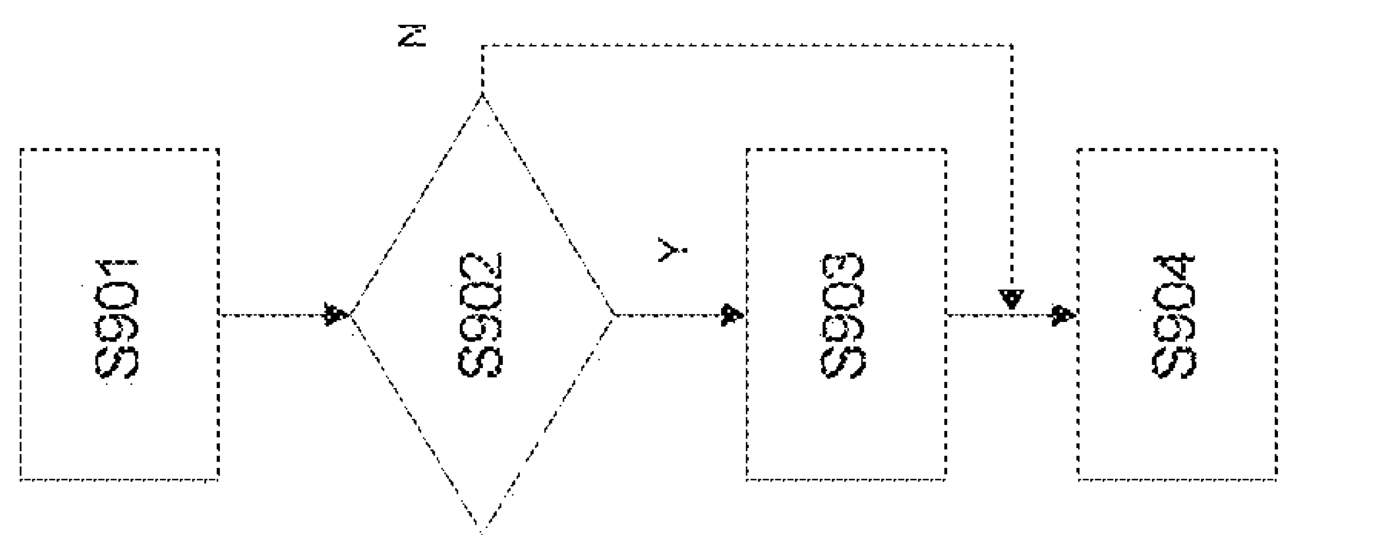


FIG 9

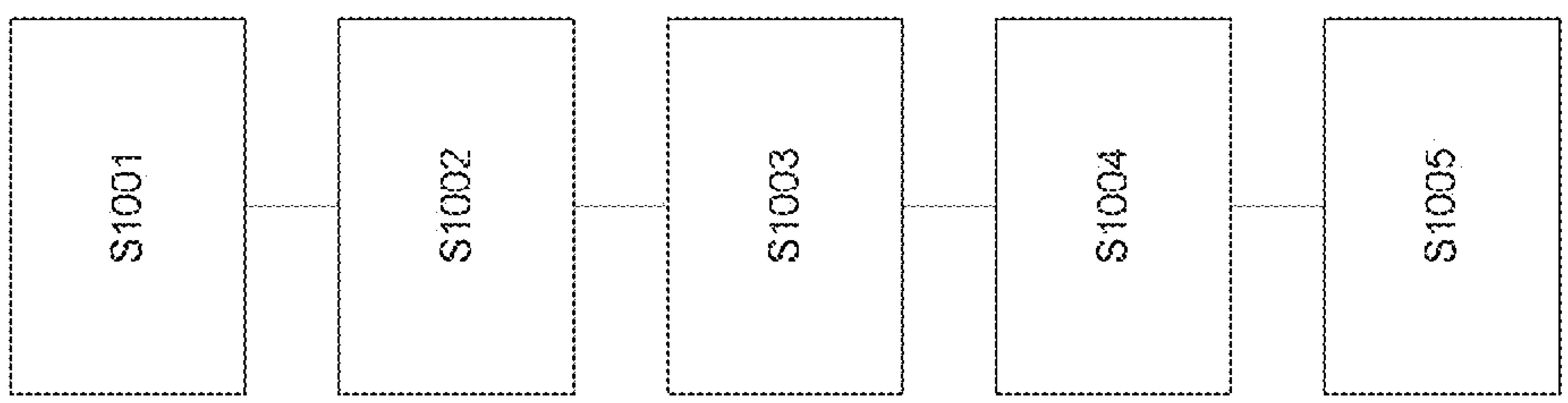


FIG 10

METHOD FOR SIGNALING A PRECODING IN A COOPERATIVE BEAMFORMING TRANSMISSION MODE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims, as a continuation, pursuant to 35 USC 120, priority to, and the benefit of the earlier filing date of, that patent application entitled "A Method for Signaling a Precoding in a Cooperative Beamforming Transmission Mode," filed on Oct. 15, 2013 and afforded Ser. No. 14/053,706, which claimed the benefit of the priority to, and the benefit of the earlier filing data of that patent application entitled "A Method for Signalling a Precoding in a Cooperative Beamforming Transmission Mode," filed on Oct. 1, 2010 and afforded Ser. No. 12/896,085, now U.S. Pat. No. 8,634,779, which claimed the benefit of the earlier filing date of that patent application filed in the European Patent Office on Oct. 5, 2009 and afforded serial number EP 09172194.4, the contents of all of which are incorporated by reference, herein.

FIELD OF THE INVENTION

The present invention relates to a method of communication in a wireless network such as a mobile communication system.

More specifically, the invention relates to a method of communication using beamforming.

BACKGROUND OF THE INVENTION

This "Background of the Invention" section is intended as an introduction to the invention for those skilled in the art. It was not intended to be and is not an admission that anything contained in this section is prior art. This section contains some information that is prior art and other information that is not prior art. Those wishing to determine the state of the prior art are directed to publications prior to the earliest priority date of this application such as patents and publications identified in the accompanying IDS.

In a cellular telecommunication system, a plurality of user terminals within a cell communicate with a primary station. With the subsequent generations of cellular systems, the achievable data rate has been increasing. In advanced systems such as UMTS (Universal Mobile Telecommunications System), LTE (Long Term Evolution) and LTE Advanced, multi-antenna transmission/reception techniques variously described as, MIMO (Multiple Input/Multiple Output), precoding or beamforming are supported for transmissions from a single cell to a mobile terminal. Thanks to the spatial selectivity of the beamforming mode, such transmission modes have enabled an important increase of the achievable data rate and of the range of communication, while maintaining the average interference level.

In order to achieve the beamforming, a transmitting station having an antenna array applies a set of complex coefficients (forming a precoding matrix or precoding vector) to a signal transmitted from its respective antennas, so that the transmission stream is spatially directed towards a receiving station. However, reception of such a beamformed transmission may require the communication of this set of complex coefficients between the transmitting station and the receiving station. In implementations of such systems, precoding codebooks are defined. These precoding codebooks may be viewed as a way of describing precoding matrix (or precoding vector) of the channel coefficients or precoding weights in a compact way,

thereby reducing the amount of required signaling for indicating the precoding. These codebooks also enable the user terminal (defined in LTE as a User Equipment or UE) to report to the network a preferred precoder for downlink transmission, in the form of an index to codebook entry. In this case, the preferred precoder is a set of complex coefficients to be applied to transmit antennas of the base station (defined in LTE as an eNodeB). Similarly, precoding codebooks may also be used by the base station to signal the precoding used for a transmission to the user terminal. This enables the user terminal to derive an appropriate phase/amplitude reference from common pilot symbols for demodulation of each downlink transmission.

In LTE, this signaled codebook index is referred to as PMI (Precoding Matrix Indicator). The same codebook may be used on one hand to signal to a user terminal the precoding vector or matrix which is actually applied in the downlink by a base station and on the other hand to feed back the preferred precoding matrix by the user terminal to enable a phase/amplitude reference to be derived. Alternatively, the reference(s) may be provided by precoded reference symbols (i.e. dedicated reference symbols).

Recently, it has been proposed to use cooperative beamforming, i.e. beamforming using antennas from multiple cells or multiple base station sites (under the description of CoMP or Co-operative Multi-Point transmission). Such systems are introduced in FIGS. **1** to **3**. In such a system, a user terminal **110** within a serving cell **101***a* communicates in normal (i.e. single cell) mode with a primary station **100***a*. In normal beamforming mode, the primary station **100***a* applies a set of precoding weights to the signal to be transmitted from its transmit antennas **104***a* to create a spatial stream **105***a* directed towards the user terminal **110**.

In a cooperative beamforming mode, a second primary station **100***b* in a neighboring cell **101***b* uses some of its antennas **104***b* to transmit in a cooperative way the same signal **105***b* as the signal **105***a* transmitted by the first primary station **100***a* to the user terminal **110**. The spatial stream now comprises two components **105***a* and **105***b*. As explained above, the user terminal **110** needs to feed back a channel state estimate based on measurements on received reference symbols. This estimate in this example is an indication of a preferred precoding matrix (or vector if there is only one transmission stream) in the form of a codebook index.

As illustrated on FIG. **1**, it may be possible to report a PMI for each co-operating cell, i.e. the user terminal signals transmit an indication of a first preferred precoding matrix **111***a* for the serving cell **101***a* to the first primary station **100***a* and an indication of a second preferred precoding matrix **111***b* for the neighboring cell **101***b* to the second primary station **100***b*. Thus, the first and second base stations **100***a* and **100***b* may use different precoding in order to have a fine adjustment of their respective transmission beams to the user terminal. This means that the user terminal needs to feed back as many PMIs as there are cooperating cells. This may represent a great amount of signaling and overhead.

In order to reduce this signaling, as illustrated on FIG. **2**, it could be possible that the user terminal **110** transmits only one PMI to the cooperating cells base stations **100***a* and **100***b*. On FIG. **2**, the user terminal **110** makes an estimate of the received transmission channels by means of measurements on reference symbols, and establishes one PMI **112** which is transmitted to both base stations **100***a* and **100***b*. This means that the base station **100***a* and the base station **100***b* apply the same precoding. Thus, the drawback of this is a lack of flexibility. Moreover, in case of more than two cooperating cells, it may be difficult to obtain an efficient beamforming.

Another approach illustrated on FIG. 3, may be described as SFN with antenna selection. Here SFN is "single frequency network", which implies that the same signal is transmitted from more than one cell. The user terminal **110** reports a value of precoding matrix **113***a* which is to be applied by all the co-operating cells **101***a* and **101***b*. Additionally the user terminal **110** signals in a further signaling message **113***b* whether particular antennas should be switched off. This means that the remaining antennas are "selected". In a typical implementation of this technique for the case of four transmit antennas per cell, up to one antenna may be switched off per cell. The user terminal then needs to search the possible combinations of PMI and antenna selection for the one which will give the highest data rate.

This permits some more flexibility in the adjustment of the precoding. However, the antenna selection feedback needs some data. For instance, in the above example, the antenna selection for one cell needs at least three bits (four different antenna values and the case where no antenna is switched off). This means that this causes overhead and still a significant amount of signaling. Moreover, this may lead for some base stations to a potential power imbalance between the different antennas. This may thus reduce the total available power to that provided by the remaining on antennas, and this would affect the achievable transmit data rate.

SUMMARY OF THE INVENTION

It is an object of the invention to propose a method for operating a telecommunication system which alleviates the above described problems.

It is another object of the invention to propose a method for operating a secondary station which proposes a good tradeoff between amount of signaling and flexibility of the precoding.

To this end, in accordance with an aspect of the invention, a method is proposed for operating a secondary station in a network, the secondary station comprising a transceiver adapted for simultaneously receiving transmissions from a primary station controlling a first cell and at least one primary station controlling a second cell, the method comprising the secondary station:

(a) selecting a first precoding matrix for the first cell out a primary set of precoding matrices for the first cell,

(b) selecting, in dependence on the first precoding matrix in accordance with a precoding scheme, a subset out of a secondary set of precoding matrices for the second cell, the subset consisting of at least one precoding matrix for the second cell,

(c) selecting a second precoding matrix for the at least one second cell out of the selected subset of precoding matrices for the second cell, and

(d) transmitting a first indicator representative of the first precoding matrix.

In accordance with a second aspect of the invention, it is proposed a secondary station comprising:

a transceiver adapted for simultaneously receiving transmissions from a primary station controlling a first cell and at least one second primary station controlling a second cell,

control means:

for selecting a first precoding matrix for the first cell out a primary set of precoding matrices for the first cell,

for selecting a subset of precoding matrices for the second cell in dependence on the first precoding matrix out of a set of subsets of precoding matrices for the second cell, and

for selecting a second precoding matrix for the second cell out of the subset of precoding matrices for the second cell, the transceiver being arranged for transmitting a first indicator representative of the first precoding matrix and a second indicator representative of the second precoding matrix.

As a consequence, the secondary station may signal a single first precoding matrix indicator and keep a certain amount of flexibility in the choice of precoding for the second precoding matrix. It is also possible for the secondary station to signal information upon the second precoding matrix by means of a second indicator representative of the second precoding matrix. But since the choice of precoding for the second precoding matrix is limited to a subset, the amount of data required for the second indicator is reduced.

Moreover, in an embodiment of the invention, the second precoding matrix represented by the second indicator is based on the value of the first indicator, so that the amount of data used for transmitting the second indicator is less than the amount of data used for transmitting the first indicator. Indeed, the values of the second precoding matrix are limited in accordance with the value of the first precoding matrix. This thus enables the use of a small or reduced second indicator in terms of data bits, because the possible values of the second indicator is limited to a subset of values. This permits flexibility without requiring too much additional signaling in terms of data bits.

In accordance with this aspect of the invention, at step (b), the subset of precoding matrices is selected in accordance with a precoding scheme. Thus, it is possible to firstly select a precoding scheme convenient for the particular conditions and topology of the network (e.g. whether the cells are served by a single primary station or by different primary station, or whether the signals from the two cells are identical or not), signal the selected precoding scheme beforehand, and then apply this precoding scheme according to which a value of first precoding matrix for the first cell leads to a restricted subset of second precoding matrices for the second cell. Thus, even if the flexibility is restricted to a subset of values for the second precoding matrix, this ensures though that the restricted values are suitable for the situation experienced by the secondary station.

In accordance with a variation of the above variant of the first embodiment, the selected precoding scheme is generated by the secondary station on the basis of statistics recorded by the secondary station on combinations of a precoding matrix selected from a codebook for the first cell and a precoding matrix selected from a codebook for the second cell. Such a precoding scheme is thus adapted and suitable for the situation experienced by the secondary station. It ensures that the limited flexibility avoids restricting the secondary station to unsuitable precoding matrix values.

The present invention also relates to a method for operating a secondary station in a network, the secondary station comprising a transceiver adapted for simultaneously receiving transmissions from a primary station controlling a first cell and at least one primary station controlling a second cell, the method comprising the secondary station signaling a first precoding matrix indicator representative of a first precoding matrix for the first cell and a second precoding matrix indicator representative of a second precoding matrix for the second cell, wherein the amount of data used for the second indicator is less than the amount of data used of the first indicator.

In accordance with a third aspect of the invention, a method is proposed for operating a primary station in a network, the primary station being arranged for operating a first cell, the primary station comprising a first transceiver adapted for transmitting transmissions in cooperation with at least a transceiver of primary station dedicated to a second cell, the method comprising the primary station:

(a) selecting a first precoding matrix for the first cell out of a primary set of precoding matrices for the first cell,

(b) selecting, in dependence on the first precoding matrix in accordance with a precoding scheme, a subset out of a secondary set of precoding matrices for the second cell, the subset consisting of at least one precoding matrix for the second cell,

(c) selecting a second precoding matrix for the at least one second cell out of the selected subset of precoding matrices for the second cell, and

(d) transmitting a first indicator representative of the first precoding matrix to the secondary station.

In accordance with a fourth aspect of the invention, it is proposed a primary station comprising a transceiver for operating a first cell, said transceiver being adapted for transmitting transmissions in cooperation with at least a transceiver of primary station dedicated to a second cell, the primary station being arranged:

for selecting a first precoding matrix for the first cell out a primary set of precoding matrices for the first cell,

for selecting a subset of at least one precoding matrix for the at least one second cell in dependence on the first precoding matrix, out of a set of subsets of precoding matrices for the second cell,

for selecting a second precoding matrix for the at least one second cell out of the selected subset of precoding matrices for the second cell, and

the transceiver of the primary station being arranged for transmitting a first indicator representative of the first precoding matrix to the secondary station.

These and other aspects of the invention will be apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail, by way of example, with reference to the accompanying drawings, wherein:

FIGS. **1-3**; already described, are block diagrams of architectures that have been discussed in 3GPP.

FIG. **4** is a block diagram of a communication system in accordance with a first embodiment of the invention.

FIG. **5** is a schematically representation of the precoding scheme used in the first embodiment.

FIG. **6** is a block diagram of a communication system in accordance with a second embodiment of the invention.

FIG. **7** is a block diagram of a communication system in accordance with another variant of the second embodiment.

FIG. **8** is a block diagram of a communication system in accordance with still another variant of the second embodiment.

FIG. **9** is a flowchart representing a method of operating a system in accordance with a third embodiment of the invention.

FIG. **10** is a flowchart representing a method of designing a precoding scheme in accordance with the first embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a telecommunication system comprising a plurality of cells, each cell being controlled by a primary station, said primary station being able to communicate with secondary stations that are within the cell. Such a system will be detailed with reference to the system depicted on FIG. **4**.

As shown on FIG. **4**, a secondary station **410** contained in cell **401***a* communicates with a primary station **400***a*. In an exemplary embodiment of the invention, such a telecommunication system operates under the UMTS specifications or LTE specifications. Accordingly, the primary station **400***a* may be an eNodeB and the secondary station **410** is a User Equipment (UE). A second cell **401***b* neighboring cell **401***a* is represented on FIG. **4**. This cell **401***b* is controlled by a primary station **400***b*. On FIG. **4**, the primary stations **400***a* and **400***b* are represented as two different primary stations, however, it should be noted that it is possible that a single primary station may control a plurality of cells (usually three in current networks).

For the sake of clarity only one secondary station is represented, however, a plurality of secondary stations may be within a cell.

Each primary station **400***a* and **400***b* comprises an antenna array **404***a* and **404***b* respectively having a plurality of antennas, in this example four antennas per cell. In accordance with a cooperative beamforming mode, the secondary station **410** may receive signals from its cell primary station **400***a* and from neighboring cells primary stations, in this example from primary station **400***b*. The primary stations **400***a* and **400***b* transmit to the secondary station **410** by using each set of respective precoding coefficients using a respective data stream **4002***a* and **4002***b* and respective sets of reference symbols **4001***a* and **4001***b*. In this cooperative beamforming mode, the data streams are identical. Therefore the two data streams **4002***a* and **4002***b* can be considered as a single joint transmission. In another cooperative beamforming mode the data streams may be different. The reference symbols **4001***a* and **4001***b* may be used by the secondary station **410** for decoding efficiently the data streams **4002***a* and **4002***b*. On the basis of these reference symbols **4001***a* and **4001***b*, or on other reference symbols embedded in the downlink channels transmitted by the primary stations **400***a* and **400***b*, the secondary station **410** estimates channel coefficients in order to establish a preferred precoding matrix for the respective cells.

In accordance with a first embodiment of the invention, the secondary station **410**, based on the estimation of the channel coefficients, chooses a first preferred precoding matrix in a primary codebook for the cell **401***a*. The secondary station **410** uses the primary codebook to extract an index that may then be signaled to the first cell **401***a* by means of a signaling message **411***a*.

Furthermore, the secondary station may choose in this first embodiment a preferred precoding matrix for the second cell **401***b* out of a secondary precoding codebook. This secondary precoding codebook is a limited codebook in the sense that it contains a subset of precoding matrices, namely a limited number of precoding matrices (e.g. 1, 2, or more but less than the total number of the conventional set of available precoding matrices for a conventional secondary codebook). This secondary codebook depends on the value of the preferred precoding matrix for the first cell **401***a*, or on the value of the index to be signaled in the signaling message **411***a*. The signaling messages may be signaled on an uplink control channel like PUSCH or PUCCH in LTE.

If the number of entries contained in the secondary codebook is more than one, an index to the secondary codebook entry is signaled in a signaling message **411***b*. However, it is to be noted that in variation of this embodiment this second cell precoding matrix is uniquely determined by the first cell precoding matrix and does not need to be signaled (e.g. it may have the same value). In this first embodiment of the invention, the signaling messages **411***a* and **411***b* are signaled respectively to primary stations **400***a* and **400***b*. However, in a variant of this embodiment, both signaling messages **411***a* and **411***b* are signaled to at least one of primary stations **400***a* and **400***b*, e.g. the primary station of the serving cell; hence primary station **400***a*. Then, the primary station **400***a* may retransmit the signaling message to the second primary station **400***b*, or compute the precoding coefficients for the two primary stations, and forward the precoding coefficients to the primary station **400***b*. In addition, the computed precoding coefficients or information about the coefficients may be forwarded to the secondary station. This could be in the form of explicit signaling or by means of precoded reference symbols.

This embodiment of the invention addresses some problems of the prior art, which are the number of bits to send multiple precoding matrix indexes (i.e. signaling overhead) in the messages from the secondary station **410** to the network, i.e. to the primary station **400***a* and/or **400***b*, and the computational complexity at the secondary station of searching all possible combinations of precoding matrix index for each cell for the highest bit rate, or the computational complexity of searching a single large codebook covering all the cooperating cells.

It also aims to offer more flexibility in choice of codebook entries and potentially better performance with reasonable computational complexity and signaling overhead, in comparison with systems like the one illustrated on FIG. **2**.

This first embodiment of the invention is based on the recognition that the radio channels from different access points/cells to a given secondary station are likely to have some properties which are correlated. These correlated properties are established by means of precoding scheme giving the correspondence between the values of the primary codebook and the subsets of precoding matrices of the secondary codebook. In order that the primary stations of the cells **401***a* and **401***b* know the correspondence between the primary codebook and the secondary codebook, the secondary station signals beforehand a correspondence matrix by means of the signaling message **411***c*. Alternatively, a precoding scheme can be pre-established and known in advance from both the primary station and the secondary station. In a preferred example of this first embodiment, the signaling message **411***c* is a higher layer signaling message so that it does not affect the physical layer uplink signaling resources. Moreover, this precoding scheme may not need to be updated too often, only if the secondary station has moved so much that the whole topology of the network has completely changed (from the viewpoint of the secondary station).

In FIG. **5** is illustrated schematically the correspondence between the primary and secondary codebooks. In this precoding scheme, the primary codebook values **51** are linked to subsets of three values **52** of the secondary codebook. In this example, the number of possible values in the subset is constant, however, this may not always be the case and some primary codebook values **51** may be linked to smaller subsets of secondary codebook values **52**.

Moreover, FIG. **5** shows the index that will be signaled in signaling messages **411***a* and **411***b*. The indexes **511** for the primary codebook **51** are in this example a complete PMI, which can be represented with three bits for the codebook size shown in FIG. **5**. Then, for signaling the secondary codebook index, a smaller codeword **521** (here two bits since the subset of precoding matrices can have three values) is needed to be signaled in the signaling message **411***b*. Thus, the amount of data used for transmitting the second indicator **521** is less than the amount of data used for transmitting the primary codebook value **511**. In variation of this embodiment the index for the primary codebook and the index for the secondary codebook may be jointly transmitted as a combined index, which may be more efficient, for example if the number of entries in the primary codebook and/or secondary codebook is not a power of two, or the number of entries in the secondary codebook varies depending on the entry in the primary codebook.

The secondary station **410** may also report to the network the preferred transmission rank (i.e. the number of spatial channels to be used for the transmission, which is equivalent to the number of antenna ports) and an indication on the channel quality. Channel quality is typically indicated by a channel quality indicator (CQI). This is typically indicates a data rate at which packet transmissions can be received with pre-determined error probability.

In accordance with an example of the first embodiment, the secondary station makes channel measurements on the potentially cooperating cells and identifies suitable subsets from the second set of precoding matrices of the secondary codebook (hereinafter 'second set') for association with codebook entries in the first set of precoding matrices of the primary codebook (hereinafter 'first set') in order to establish the precoding scheme of FIG. **5**. In another example different from the precoding scheme of FIG. **5**, the aim of the secondary station **410** is to find the two best codebook entries from the second set to be associated with a given codebook entry from the first set. Signaling one of two entries from the second set would only require one additional bit.

FIG. **10** represents one of the possible methods for finding good codebook contents:

- In each subframe containing suitable reference symbols, at step S**1001** find the data rate for each combination of codebook entry (i.e. corresponding to the combination of the codebook precoding matrices) from the first set and from the second set.
- then, at step S**1002**, collect statistics of the data rate (e.g. average data rate) for each combination of codebook entry from the first set and from the second set.
- and at step S**1003**, for each codebook entry from the first set, identify the two codebook entries selected from the second set which give the highest average data rates.

Thus, this permits to obtain, on the basis of some statistics, a precoding scheme adapted to the situation experienced by the secondary station.

Another method may be the following:

- In each subframe containing suitable reference symbols find the combination of codebook entry from the first set and from the second set which would give the highest bit rate.
- for each codebook entry selected from the first set, collect statistics for each of the codebook entries selected from the second set (e.g. for a given codebook entry from the first set, record the number of times a given codebook entry is selected from the second set).
- For each codebook entry from the first set, identify the most frequently selected codebook entry or entries from the second set.

For either method, the resulting proposed codebook contents are summarized in a precoding scheme that is signaled to the network, preferably as higher layer signaling at step S**1004**. The network then confirms the proposed precoding scheme and corresponding codebooks (preferably via physical layer signaling) or signals a new one (preferably via higher layer signaling) at step S**1005**. If no precoding scheme or codebook is indicated by the network a fixed (or predetermined) precoding scheme is used.

In a variation of this first embodiment, the secondary station may signal a recommendation for only part of the precoding scheme. The network may then decide the remaining parts of the precoding scheme and the corresponding codebooks, or the remaining parts may be fixed or pre-determined. For example, the network may signal the contents of part of the codebook and the remaining parts are fixed or pre-determined, then the secondary station uses the methods described above to establish its recommended precoding scheme for the non-fixed parts of the codebook.

In accordance with this first embodiment, the secondary station makes channel measurements on the cooperating cells and identifies suitable subsets from the second set for association with codebook entries in the first set. The resulting codebook design is then signaled to the network.

The network can either signal confirmation of the UE codebook, or signal the contents of a different codebook.

The same principle can be used for a codebook with more than 2 entries in the subset from the second codedbook and for more than two cooperating cells. However, it is to be noted that if the secondary station location changes, then the codebook could need to be updated. It is possible to configure the secondary station so that upon detection in a big variation of location (either by a change in receive power or by help of embedded GPS, or other geolocalization monitor), it triggers the establishment of a new precoding scheme.

In accordance with a second embodiment of the invention illustrated on FIG. **6**, the precoding scheme may be based on statements regarding the topology of the network and the situation of the secondary station within the cell. In FIG. **6**, a secondary station **610** is within a serving cell **601***a* and communicates with a primary station **600**. In an example of this second embodiment of the invention, such a telecommunication system operates under the UMTS specifications or LTE specifications. Accordingly, the primary station **600** may be an eNodeB and the secondary station **610** is a User Equipment (UE). A second cell **601***b* neighboring cell **601***a* is represented on FIG. **6**. This cell **601***b* is controlled by the same primary station **600**.

For the sake of clarity only one secondary station is represented, however, a plurality of secondary stations may be within a cell.

Primary station **600** comprises an antenna array divided in two subarrays **604***a* and **604***b* respectively dedicated to each respective cell, in this example four antennas per cell. In accordance with a cooperative beamforming mode, the secondary station **610** may receive signals from antennas **604***a* and **604***b* dedicated to cells **601***a* and **601***b*.

In accordance with this embodiment, a single primary station **600** serves the two cooperating cells with antenna arrays aligned in the same direction, the general direction of the transmission beam is the same for the two antennas as represented on FIG. **6** with the angle α.

As a simple example for a better understanding of this second embodiment, let us consider that the cells **601***a* and **601***b* (at the same frequency) supported from the same base station site **600** are using uniform linear antenna arrays, with rank-**1** transmission in a free-space/line-of-sight channel (LOS). In this case the optimum precoding coefficients depend mainly on the angle α with respect to the antenna array and the codebook can be based on DFT coefficients (i.e. for a given spatial signature, in this case a unique direction with respect to the antenna array, the corresponding precoding coefficients can be obtained via a Discrete Fourier Transform). For a secondary station **610** likely to benefit from CoMP (Cooperative Multipoint Transmission), i.e. in an area served by the two cells, the angles with respect to the two antenna arrays are likely to be similar. Therefore if the secondary station selects optimum precoding coefficients from a codebook for the serving/first cell, the set of optimum coefficients for the other/second cell is likely to correspond to a similar angle, and therefore the most likely candidates in the codebook for the second cell can be determined according to the codebook entry selected for the serving cell. For example, if the codebook entries are ordered according to angle, then depending on the particular geometrical configuration (for example with antenna arrays **604***a* and **604***b* pointing in different directions), the most likely codebook entries for the second cell could be the same or adjacent to the codebook entry for the first cell, or in a mirror position in the codebook. In this case at least one of the codebook entries for the second cell should be identical to the corresponding codebook entry for the first cell.

Thus, a precoding scheme can be established easily based on the statement that the two cells **601***a* and **601***b* are controlled by the same primary station site. The same approach can be applied in a slightly different embodiment where the antenna arrays **604***a* and **604***b* serve the same cell. This would allow a codebook designed for 4 antennas to be used in a cell with 8 antennas.

For the example given, the precoding codebook entries preferred by the secondary station could be signaled to the primary station in terms of a codebook index (e.g. four bits) for the first cell **601***a* and an offset (e.g. one or two bit) to indicate a codebook index for the second cell **601***b*.

For a full codebook search, the secondary station could estimate the achievable data rate with each codebook entry from the first codebook in combination with each offset to the second codebook (e.g. 4+2=6 bits or sixty-four combinations).

The two main advantages of this second embodiment are the reduced number of bits to signal the codebook indices, compared with the full number of bits for each codebook and the reduced computational complexity from searching a smaller number of codebook combinations. Moreover, there is no need in this embodiment compared with the first embodiment to compute a precoding scheme based on statistics, reducing thus the computation requirement in the secondary station.

A similar approach may be chosen for other configurations of the network. As illustrated in FIG. **7**, a secondary station **710** is within a serving cell **701***a* and communicates with a primary station **700***a* operating the serving cell **701***a*. The primary station **700** may be an eNodeB and the secondary station **710** may be a User Equipment (UE). A second cell **701***b* which is a neighbor to cell **701***a* is represented on FIG. **7**. This cell **701***b* is controlled by a second primary station **700***b*.

For the sake of clarity only one secondary station is represented, however, a plurality of secondary stations may be within a cell.

Based on the recognition that the angles α**1** and α**2** of the beams with a reference are related one to another, it is possible to establish a precoding scheme from the topology of the network.

Let us consider that the cells **701***a* and **701***b* (at the same frequency) supported from two base station sites **700***a* and **700***b* are using uniform linear antenna arrays, with rank-**1** transmission in a free-space/line-of-sight channel (LOS). In this case the optimum precoding coefficients depend mainly on the angle α**1** and α**2** with respect to the antenna array and the codebook can be based on DFT coefficients. For a secondary station **710** likely to benefit from CoMP, i.e. on the border between two cells, the angles with respect to the two antenna arrays are likely to be related (i.e. with opposite or mirrored values). If the reference is the axis linking the two base station sites, the angle α1 equals approximately −α2 if it is considered that the cells have the same size. Therefore if the secondary station selects optimum precoding coefficients from a codebook for the serving/first cell **701***a*, the set of optimum coefficients for the other/second cell **701***b* is likely to correspond to an opposed angle, and therefore the most likely candidates in the codebook for the second cell can be determined according to the codebook entry selected for the serving cell. For example, if the codebook entries are ordered according to angle, then, depending on this particular geometrical configuration, the most likely codebook entries for the second cell could be in a mirror position in the codebook. Thus, it could be given by an offset minus the value of the first codebook index.

For a secondary station in a location that leads to the same or adjacent codebook entries in the second cell, as in FIG. **6**, an example of such a precoding scheme could be represented as follows:

Codebook entry from first codebook (for first cell)	First associated entry from the second set (for second cell)	Second associated entry from the second set (for second cell)
1	1	2
2	2	3
3	3	4
4	4	5
5	5	6
6	6	7
7	7	8
8	8	6

This means that, for example if codebook entry **5** is chosen for the first cell (which could be signaled by three bits), then either codebook entry **5** or **6** could be used for the second cell (which could be signaled by one bit).

For a secondary station in a location that leads to mirror codebook entries in the second cell, as in FIG. **7**, an example of such a codebook could be represented as follows:

Codebook entry from first codebook (for first cell)	First associated entry from the second set (for second cell)	Second associated entry from the second set (for second cell)
1	8	7
2	7	6
3	6	5
4	5	4
5	4	3
6	3	2
7	2	1
8	1	3

It is to be noted that the same applies for more than two cooperating cells. As shown on FIG. **8**, a secondary station **810** receives the cooperating transmission from three cells **801***a*, **801***b*, or **801***c* controlled each by a respective primary station **800***a*, **800***b* or **800***c*.

As in the case of FIG. **8**, the angles α**1**, α**2**, and α**3** are related to one another. As a consequence, the precoding scheme may be predetermined to take this into account. As a first approximation, the codebook entries of the secondary codebook and of the tertiary codebook may be offset by a constant to take into account these relationships.

Then, in accordance with the second embodiment, the values of the first precoding matrix are signaled in a similar way as in the first embodiment which is not repeated for reasons of economy. Furthermore, the values of the second precoding matrix may be signaled as in the first embodiment in the case that there is more than one secondary codebook entry corresponding to the first precoding matrix value. If not, the signaling can be omitted since the primary stations will be aware of the second precoding matrix scheme.

Regarding the signaling of the precoding scheme in the second embodiment, a similar signaling may be carried out as in the first embodiment. However, it is also possible in a variation of the second embodiment to signal the situation that the secondary station is experiencing, i.e. statements on the topology of the network and on the situation of the secondary station in this network. Moreover, since the primary stations are aware of the topology of the network, the primary station may signal to the secondary station a recommended or a default precoding scheme. This permits avoiding the signaling of a complete precoding scheme which may be quite large in terms of overhead or signaling.

The optimum association between the first set of codebook entries for the first cell and the set of subsets for the first cell is likely to depend on the deployment configuration and the propagation environment. It would be desirable that this association is identified as in the second embodiment. In general this can be done by making channel measurements on each of the (potentially) cooperating cells at the UE, and reporting them to the network. However, this is likely to result in considerable signaling overhead.

Variations in this embodiment are possible as follows:

In selecting the PMI the UE considers that the first coefficient in the PMI as applied to each cell may be selected to have zero value. For three cells this requires up to three bits of signaling to indicate the selected combination of zero value coefficients for three cells. In a further variation, the case where all the first PMI coefficients are zero is not allowed. In a further variation, the case where all the first PMI coefficients are non-zero is not allowed.

In selecting the PMI, the UE considers the following seven possibilities for each cell, which would require up to nine bits of signaling to indicate the selected combination for three cells. Some combinations may not be allowed (e.g. no transmission on all three cells, only one mapping between spatial channels and codewords allowed for the serving cell):

- Rank-**2** transmission of codeword **1** on spatial channel **1** and codeword **2** on spatial channel **2**
- Rank-**2** transmission of codeword **1** on spatial channel **2** and codeword **2** on spatial channel **1**
- Rank-**1** transmission of codeword **1** on spatial channel **1**
- Rank-**1** transmission of codeword **2** on spatial channel **1**
- Rank-**1** transmission of codeword **1** on spatial channel **2**
- Rank-**1** transmission of codeword **2** on spatial channel **2**
- No transmission

In selecting the PMI, the UE assumes that rank-**2** transmission is only carried out by the serving cell. The other cells only transmit with rank-**1** (i.e. one spatial channel and one codeword). If the UE prefers Rank-**2** transmission according to some criterion, the UE assumes that the serving cell transmits two codewords with Rank-**2** according to the value of the selected PMI. Some options for the other cells are:

The UE assume that other cells only transmit the first spatial channel. This means that the possibilities are the same for Rank-**1** or Rank-**2** transmission from the serving cell: either rank-**1** or no transmission from each cooperating cell. These options could be indicated using four bits.

The UE selects which spatial channel and which codeword should preferably be transmitted by which of the other cells. The various possibilities (including Rank-**1** or Rank-**2** transmission from the serving cell) could be signaled with six bits:

Rank-**1** transmission of codeword **1** on spatial channel **1**

Rank-**1** transmission of codeword **2** on spatial channel **1**

Rank-**1** transmission of codeword **1** on spatial channel **2**

Rank-**1** transmission of codeword **2** on spatial channel **2**

No transmission

The UE selects a PMI for the first cell, and possible modifications of the PMI in the other-cells according to one of the following variations:

A cyclic shift to be applied to the matrix/vector indicated by the PMI obtain the precoding matrix/vector for each of the other cells.

A phase rotation to be applied to obtain the precoding matrix/vector for each of the other cells.

A cumulative phase rotation to be applied to obtain the precoding matrix/vector for each of the other cells. This would apply a phase slope across the matrix/vector, which is equivalent to an angular shift in the resulting beam pattern.

A combination of antennas for which the phase of the precoding coefficient is rotated to obtain the precoding matrix/vector for each of the other cells. The phase rotation can be fixed, preferably at 180 degrees (i.e. inversion). The amount of phase rotation may be signaled.

In variations of these above first and second embodiments, the secondary index may be replaced by:

a cyclic shift to be applied to a precoding matrix, e.g. the primary precoding matrix, to obtain the second precoding matrix.

a phase rotation to be applied to a precoding matrix, e.g. the primary precoding matrix, to obtain the second precoding matrix;

a parameter of a function for computing the phase rotation to be applied to the precoding coefficients of a given antenna from the antenna number to obtain the second precoding matrix from a precoding matrix, e.g. from the primary precoding matrix;

a combination of antennas for which the phase of the precoding coefficients is rotated to obtain the second precoding matrix from a precoding matrix, e.g. the primary precoding matrix.

In accordance with the invention, and as represented on FIG. **9**, a method is presented in an exemplary system like LTE with four transmit antennas per cell at the eNB (eNodeB), and two receive antennas at the UE.

At step S**901**, the UE estimates the PMI for the serving cell in a way which is similar to release 8 of UMTS, i.e. the PMI which would give the highest data rate. At step **902**, if the UE considers that according to some criterion one or more cooperating cells should be included, then for the serving cell and up to two additional co-operating cells, further information is provided at step S**903**. This additional information comprises the identity of the preferred cooperating cells (if any), the preferred transmission rank (which also determines the number of codewords) and additional information which modifies how the PMI is to be interpreted for each of the cooperating cells. For rank-**1** transmission the PMI is a vector and one codeword would be transmitted at step S**904**. The signaling is physical layer signaling via PUCCH or PUSCH. For higher rank the PMI is a matrix. In this example, the maximum rank is **2**, which implies that two codewords would be transmitted by the eNB in the downlink. The UE may also report a CQI on the assumption that the network transmits according to the PMI and additional information at step S**904**.

Typically, the specification for systems like LTE makes use of the term "antenna port", which is effectively a virtual antenna which may correspond to a single physical antenna or may be derived by a linear combination of signals from more than one physical antenna. For convenience, we use the term "antenna", but this could also be understood as "antenna port".

In the case of non-DFT codebooks (e.g. for non-LOS channels), it is not necessarily the case that the appropriate entries for the second cell are adjacent to the entry selected for the first cell. In some cases it may be possible to determine the appropriate entries analytically as in the second embodiment. Otherwise they may be determined empirically (e.g. by observation of selected codebook entries in a simulation or in measurements) as in the first embodiment, or some codebook design approach could be used (e.g. brute-force search for a good codebook, or genetic algorithm).

To summarize, the CoMP codebook according to the embodiments of the invention comprises a first set of precoding matrices for the first cell. For the second cell, there is a subset of a second set precoding matrices, said subset being associated with each matrix from the first set of precoding matrices. Each subset may have different members. The second set may have the same members as the first set. And so on for third and further additional cells as required. In the case of rank-**1** transmission, the matrices may be vectors.

In accordance with a third embodiment, the precoding scheme may be used as well (or only) by a primary station involved in a cooperative beamforming. In a similar way as the embodiments described previously, the primary station selects a first precoding matrix to signal the precoding applied on the antennas of a first primary station, e.g. itself or another primary station involved in the cooperative beamforming. Then, the precoding of a second primary station may be limited to a subset of precoding matrices (e.g. 1, 2, 3 matrices but less than the whole set of available precoding matrices for the second cell). Then, the precoding of the second cell is chosen in the limited set of precoding matrices and is applied to a primary station involved in the cooperative beamforming. The first primary station may signal the first precoding matrix (by use of a precoding matrix index) and possibly information regarding the second precoding matrix.

The present invention shall not only be construed to the above embodiments and it will be clear for someone skilled in the art that the below variants and examples may be adapted in various implementations of the invention. Some exemplary extensions or alternatives to the above embodiments described below are possible. For some codebooks the first coefficient in the matrix/vector of each entry has the same value (e.g. 1). Since it is unlikely that the optimum value for this coefficient is the same for every cooperating cell, this element can always be selected as "off" in the subsets for the second cell. This may be subject to the condition that the first coefficient is not "off" in the first codebook entry for the first cell. This reduces the number of bits needed to signal the antenna selection information.

In the case of rank-**2** transmission (or higher rank), it may be difficult to match the required precoding from two spatial channels from all collaborating cells. Therefore some restrictions or options could be applied:

Rank-2 transmission is only carried out by the serving cell. The other cells only transmit one spatial channel. Some options are that the UE assumes that other cells only transmit the first spatial channel or that the UE signals which spatial channel and which codeword should be transmitted by which cell.

For each cell the secondary station signals from among the following possibilities:

Rank-2 transmission

Rank-1 transmission of codeword 1 on one spatial channel

Rank-1 transmission of codeword 2 on one spatial channel

Rank-1 transmission of codeword 1 on the other spatial channel

Rank-1 transmission of codeword 2 on the other spatial channel

No transmission

It is to be noted that in receiving the resulting downlink transmission the secondary station would assume an appropriate association between DRS and codewords.

Instead of signaling a PMI and a combination of antennas which are switched "off" in each cell, the following possibilities can be signaled, in most cases with a similar number of bits:

The UE can signal a PMI for the first cell and a cyclic shift to be applied to the matrix/vector indicated by the PMI obtain the precoding matrix/vector for each of the other cells.

The UE can signal a PMI for the first cell and a phase rotation to be applied to obtain the precoding matrix/vector for each of the other cells.

The UE may signal a PMI for the first cell and a cumulative phase rotation to be applied to obtain the precoding matrix/vector for each of the other cells. This would apply a phase slope across the matrix/vector, which is equivalent to an angular shift in the resulting beam pattern.

The UE may signal a PMI for the first cell and a combination of antennas for which the phase of the precoding coefficient is rotated to obtain the precoding matrix/vector for each of the other cells. The phase rotation could be 180 degrees (i.e. inversion). This modification is proposed on the basis that if the contribution of a given antenna to the received signal is detrimental to performance (i.e. leads to destructive interference), then it would be switched "off" in AS-SFN. However, as proposed here, it may be better to reverse the phase and convert destructive interference into constructive interference. The amount of phase rotation could be signaled.

It is to be noted that in all the previous embodiments, the precoding matrix can be understood, as in the case of a rank-1 transmission, as a precoding vector.

The invention is applicable to systems using co-operative beamforming between cells which may include LTE-Advanced. The cells may be located at a single base station site, or on different sites, for example femto-cells implemented by fiber radio techniques.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

The inclusion of reference signs in parentheses in the claims is intended to aid understanding and is not intended to be limiting.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the art of radio communication.

The invention claimed is:

1. A method for operating a secondary station in a network, the method comprising:

in the secondary station:

a controller performing the acts of:

controlling a transceiver to receive transmissions from a first primary station controlling a first cell and to further receive transmissions from at least one second primary station controlling at least one respective second cell;

selecting a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell;

selecting a second precoding matrix for the second cell from a subset of precoding matrices associated with the second cell, the subset being dependent upon the first precoding matrix in accordance with a precoding scheme;

determining a first and second indicator to identify the first and second precoding matrix respectively; and

controlling the transceiver to transmit the first and second indicator;

wherein an amount of data transmitted to transmit the second indicator is less than an amount of data transmitted to transmit the first indicator.

2. A method of operating a primary station in a network, the method comprising:

in the primary station:

controlling a first cell and a second cell;

controlling a first transceiver system to transmit a signal to a secondary station in the first cell;

controlling a second transceiver system to transmit the signal to the secondary station;

receiving, from the secondary station, a first indicator of a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell;

identifying a subset of a second set of precoding matrices associated with the second cell, the subset consisting of at least one precoding matrix associated with the second cell, the subset depending on the first precoding matrix and being in accordance with a precoding scheme;

receiving, from the secondary station, a second indicator of a second precoding matrix for the second cell from the subset of precoding matrices associated with the second cell, wherein an amount of data received to determine the second indicator is less than an amount of data received to determine the first indicator;

identifying the first and second precoding matrix based on the first and second indicators, respectively; and

controlling the first and second transceiver systems to transmit the signal to the secondary station using the first and second precoding matrices, respectively.

3. A secondary station comprising: a transceiver; and the secondary station being configured to:

control the transceiver to receive transmissions from a first primary station controlling a first cell and to receive transmissions from at least one second primary station controlling at least one respective second cell, and at least at times receiving the transmissions of the first and second primary stations concurrently;

select a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell;

select a second precoding matrix for the second cell from a subset of precoding matrices for the second cell, the subset depending on the first precoding matrix and being in accordance with a precoding scheme;

determine a first and second indicator representative of the first and second precoding matrix respectively; and

control the transceiver to transmit the first and second indicators wherein an amount of data transmitted to represent the second indicator is less than an amount of data transmitted to represent the first indicator.

4. The secondary station of claim **3**, comprising a plurality of antennas connected to the transceiver, and the secondary station at times in a beamforming mode controls the transceiver to apply a set of complex coefficients based on the first precoding matrix to a signal transmitted by the plurality of antennas to spatially direct the transmission toward the first primary station.

5. A primary station comprising:

a first transceiver system that controls a first cell;

a second transceiver system that controls a second cell; and

a controller that:

receives, from a secondary system in the first cell, a first indicator of a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell, and a second indicator of a second precoding matrix for the second cell from a subset of precoding matrices associated with the second cell, the subset depending on the first precoding matrix and being in accordance with a precoding scheme; and

controls the first and second transceiver systems to transmit a signal to the secondary system using the first and second precoding matrices, respectively;

wherein an amount of data received to represent the second indicator is less than an amount of data received to represent the first indicator.

6. The primary station of claim **5**, comprising a first plurality of antennas connected to the first transceiver system and a second plurality of antennas connected to the second transceiver system, and wherein the first and second precoding matrix respectively comprise a first and second set of complex coefficients and at times the primary station in a beamforming transmission mode controls the first and second transceiver systems to respectively apply the first and second set of complex coefficients to the signal transmitted by the first and second plurality of antennas to spatially direct the transmission toward the secondary station.

7. A secondary station comprising:

a transceiver; and

the secondary station being configured to:

control the transceiver to receive transmissions from a first and a second primary stations;

select a first precoding matrix from a codebook containing at least one first set of precoding matrices;

assess a second set of precoding matrices from the codebook, wherein the codebook provides an association between the first set of precoding matrices to corresponding ones of the second sets of precoding matrices, the second set of precoding matrices being associated with the first precoding matrix;

select a second precoding matrix from the second set of precoding matrices, the selection of the second precoding matrix depending on the assessment of the second set of precoding matrices;

determine a first and second indicator to identify the first and second precoding matrix respectively; and

control the transceiver to transmit the first indicator to the first primary station and the second indicator to the second primary station wherein an amount of data transmitted to transmit the first indictor is greater than an amount of data transmitted to transmit the second indicator.

8. A tangible computer readable storage medium that is not a transitory propagating signal or wave, encoded with instructions for controlling a secondary station for performing a method for operating the secondary station in a network, the method comprising:

a controller of the secondary station performing the acts of:

controlling a transceiver to receive transmissions from a first primary station controlling a first cell while at times concurrently receiving transmissions from at least one second primary station controlling at least one respective second cell;

selecting a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell;

selecting a second precoding matrix for the second cell from a subset of precoding matrices associated with the second cell, the subset being dependent upon the first precoding matrix in accordance with a precoding scheme;

determining a first and second indicator identifying the first and second precoding matrix respectively; and

controlling the transceiver to transmit the first and second indicator;

wherein an amount of data transmitted to transmit the second indicator is less than an amount of data transmitted to transmit the first indicator.

9. A computer readable storage medium that is not a transitory propagating signal or wave, encoded with control data including instructions for controlling a primary station for performing a method of operating the primary station in a network, the method comprising:

a controller of the primary station performing the acts of:

controlling a first cell and a second cell;

receiving, from the secondary station, a first indicator of a first precoding matrix for the first cell from a first set of precoding matrices associated with the first cell and a second indicator of a second precoding matrix for the second cell from a subset of precoding matrices associated with the second cell, the subset being dependent upon the first precoding matrix in accordance with a precoding scheme; and

controlling first and second transceivers to transmit a signal to the secondary station using the first and second precoding matrices, respectively;

wherein an amount of data received to represent the second indicator is less than an amount of data received to represent the first indicator.

10. The primary station of claim **5**, wherein a controller of the primary station performs the acts of:

the controlling of the first and second cell;

the controlling of the first and transceivers for transmitting transmissions to the secondary station;

the selecting of the first precoding matrix from the first set of precoding matrices;

selecting of the subset of the second set of precoding matrices;

the selecting of the second precoding matrix from the subset; and

the receiving of the first and second indicator.

11. The secondary station of claim **3** wherein the precoding matrices of the first and second set of precoding matrices are arranged in at least one CoMP (Co-operative Multi-Point transmission) codebook and the precoding matrices in the codebook are arranged in a sequential order according to an angle of the precoding matrices and the sequential order of arrangement in the codebook of the precoding matrices is used as an index value for an indicator for identifying each matrix.

12. The secondary station of claim **3** wherein the subset of the second set of precoding matrices is one of a plurality of subsets of the second set of precoding matrices, and each subset of the plurality of subsets of the second set of precoding matrices is associated with each precoding matrix of the first set of precoding matrices.

13. The secondary station of claim **3**, wherein at least one of the first or second indicator is transmitted to at least one of the first or second primary station.

14. The secondary station of claim **3**, wherein the first primary station controls a serving cell comprising at least the secondary station and the second primary station controls a neighboring cell comprising one or more other secondary stations.

15. The secondary station of claim **3**, wherein the precoding scheme is selected from a set of precoding schemes depending on a topology of the first and second cells.

16. The secondary station of claim **15**, wherein the precoding scheme is selected depending on whether the first and second cells are controlled by a single primary station.

17. The secondary station of claim **3**, wherein the subset of precoding matrices comprises a precoding matrix identical to the first precoding matrix.

18. The secondary station of claim **3**, wherein each precoding matrix of the subset of precoding matrices is indicated by a value obtained by subtracting the indicator representative of the first precoding matrix from a corresponding constant value.

19. The secondary station of claim **3**, wherein the precoding scheme is generated by the secondary station based on performance statistics for combinations of a precoding matrix selected for the first cell and a precoding matrix selected for the second cell.

20. The secondary station of claim **3**, wherein the second indicator is representative of at least one of:

a cyclic shift to be applied to a third precoding matrix to obtain the second precoding matrix;

a phase rotation to be applied to a third precoding matrix to obtain the second precoding matrix;

a parameter of a function for computing a phase rotation to be applied to precoding coefficients of a given antenna from an antenna number to obtain the second precoding matrix from a third precoding matrix; or

a combination of antennas for which the phase of the precoding coefficients is rotated to obtain the second precoding matrix from a third precoding matrix.

21. The secondary station of claim **20**, wherein the third precoding matrix is one of: the first precoding matrix or a matrix determined according to the first precoding matrix.

22. The secondary station of claim **3**, wherein transmissions from the first cell and the second cell are rank-**1** transmissions and wherein precoding matrices are precoding vectors.

23. The secondary station of claim **3**, wherein the first primary station and the second primary station are components of a single primary station.

24. The secondary station of claim **3**, comprising the transceiver receiving the first set of precoding matrices and the second set of precoding matrices.

25. The secondary station of claim **3**, wherein the first set of precoding matrices and the second set of precoding matrices are pre-stored in the secondary station.

26. The secondary station of claim **3**, comprising transmitting a rank of the number of antennas to be used.

27. The secondary station of claim **3**, wherein the first selected matrix and the second selected matrix are selected to provide the highest average data rate of the matrices of the respective first set of matrices and subset of matrices.

28. The secondary station of claim **25**, wherein the matrices are related and wherein the first indicator identifies the first precoding matrix and the second indicator indicates the relationship between the first and second precoding matrix.

29. The secondary station of claim **3**, wherein the precoding matrices of the first and second set of precoding matrices are each assigned a unique index value and the first indicator is a first index value assigned to the first selected precoding matrix and the second indicator is an offset value from the first index value.

30. The secondary station of claim **3**, wherein at times the secondary station in a beamforming transmission mode applies a set of complex coefficients based on at least one of the first and second precoding matrix to a signal transmitted by a plurality of antennas of the secondary station to spatially direct the transmission toward a primary station.

31. The secondary station of claim **3**, wherein a controller of the secondary station performs the acts of:

controlling of the transceiver to at times simultaneously receive transmissions from the first primary station and the at least one second primary station;

the selecting of the first precoding matrix from the first set of precoding matrices;

selecting of the subset of the second set of precoding matrices;

the selecting of the second precoding matrix from the subset;

the determining the first and second indicator; and

the controlling of the transceiver to transmit the first and second indicator.

32. The primary station of claim **5**, wherein at least one of the first or second indicator is transmitted to the secondary station.

33. The primary station of claim **5**, wherein the precoding scheme is based on performance statistics for combinations of a precoding matrix selected for the first cell and a precoding matrix selected for the second cell.

34. The primary station of claim **5**, wherein the first and second precoding matrix respectfully comprise a first and second set of complex coefficients used in a beamforming mode to spatially direct the transmission toward the secondary station.

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