

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
1 April 2010 (01.04.2010)

PCT

(10) International Publication Number  
**WO 2010/036158 A1**

(51) International Patent Classification:  
*H04W 72/08* (2009.01)

(21) International Application Number:  
PCT/SE2008/051070

(22) International Filing Date:  
24 September 2008 (24.09.2008)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): TELEFONAKTIEBOLAGET L M ERICSSON (PUBL) [SE/SE]; S-164 83 Stockholm (SE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): LARSSON, Peter [SE/SE]; Ballongatan 2, 1tr, S-169 71 Solna (SE). MIAO, Qingyu [CN/CN]; Room 2-302 building 611, Bei Yuan Jia Yuan, Moli Yuan, Chao, Beijing, 100012 (CN). GAN, Jiansong [CN/CN]; Room 2-101, Building 7, Laizhen Jiayuan, Beijing, 100085 (CN).

(74) Agent: HASSELGREN, Joakim; Ericsson AB, Patent Unit LTE, S-164 80 Stockholm (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: COORDINATED MULTIPOINT TRANSMISSION/RECEPTION USER GROUPING

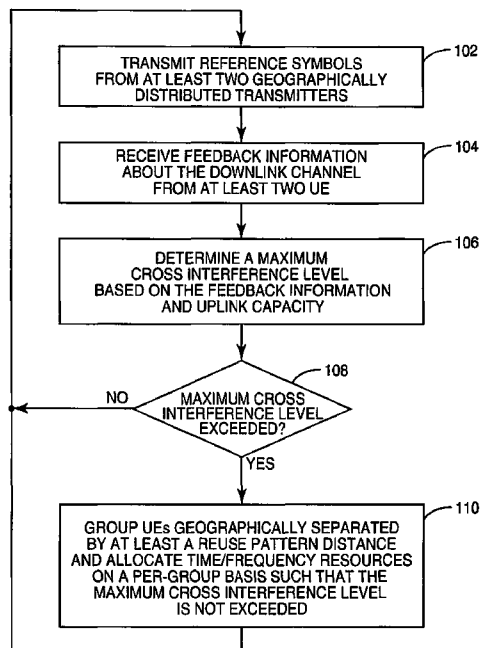
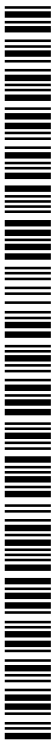


FIG. 5

(57) Abstract: User grouping is employed to tradeoff the COMP forward link capacity and required reverse link feedback, which makes the design of COMP practical and flexible. A channel element, such as the large scale fading, is measured for each distributed transmitter (14, 16) and UE (18, 20) pair based on reference signals, and the network (10) receives this information as feedback in the reverse link. The COMP determines a maximum cross interference level  $\alpha_{req}$  that is affordable, based on the available reverse link capacity for feedback. If this maximum cross interference level  $\alpha_{req}$  is exceeded, geographically separate UEs (18, 20) are divided into as few groups as possible, with UEs (18, 20) within each group separated, and the groups are allocated different time/frequency resource blocks. The grouping is done with the constraint that the cross interference does not exceed  $\alpha_{req}$ .



WO 2010/036158 A1

**Declarations under Rule 4.17:**

— *of inventorship (Rule 4.17(iv))*

**Published:**

— *with international search report (Art. 21(3))*

**COORDINATED MULTIPOINT TRANSMISSION/RECEPTION USER GROUPING****FIELD OF THE INVENTION**

**[0001]** The present invention relates generally to wireless communication networks, and in particular to a method of grouping User Equipment (UE) to improve performance in a Coordinated Multipoint Transmission/Reception (COMP) network.

**BACKGROUND**

**[0002]** A predecessor to Coordinated Multipoint Transmission/Reception (COMP), then denoted Distributed Antenna System (DAS), was originally introduced for coverage improvement in indoor wireless communications, as described by A. A. M. Saleh, A. J. Rustako Jr., and R. S. Roman, in a paper titled "Distributed antennas for indoor radio communications," published in the IEEE Transactions on Communications, vol. 35, no. 12, pp. 1245–1251, 1987. Their approach was directed towards transmission to a single user through a discrete implementation of a leaky feeder. The notion of COMP in contrast enables multiple data streams to be transmitted over an interconnected network of radioheads (or basestations) where the different signals representative of the multiple data streams may be controlled by weightings and distributed to the different radio heads. The idea of COMP may be used in downlink as well as uplink. In this invention we are concerned with downlink only. However, recent studies indicate that DAS can provide not only coverage improvement but also capacity enhancement, as described by J. Gan et al., in a paper titled "On sum rate and power consumption of multi-User distributed antenna system with circular antenna layout," published in the EURASIP Journal on Wireless Communications and Networking, vol. 2007, Article ID 89780.

**[0003]** Techniques exploring the advantages of COMP can be classified into two categories: Single-User COMP (SU-COMP) and Multi-User COMP (MU-COMP). SU-

COMP techniques attempt to improve the link quality for a single user by means of spatial multiplexing, or spatial diversity. However, SU-COMP techniques can not manage the mutual interference among users. Accordingly, Radio Resource Management (RRM) schemes are needed for geographically separated users that are using the same time/frequency resources. The reuse distance restricts the capacity increase of SU-COMP.

**[0004]** MU-COMP techniques jointly process signals to/from multiple users and attempt to improve the overall system performance. MU-COMP is quite similar to Multi-User Multiple-Input Multiple-Output (MU-MIMO) systems. Accordingly, techniques developed for MU-MIMO system, such as Zero-Forcing (ZF) beamforming and Dirty Paper Coding (DPC), can be directly applied to MU-COMP. Some of these techniques are described by G. J. Foschini et al., in a paper titled "The value of coherent base station coordination," published in the Proceedings of the 39th Annual Conference on Information Sciences and Systems (CISS '05), March 2005.

**[0005]** MU-COMP techniques can achieve the capacity limit provided by a COMP, as there is no need to separate users in time/frequency to avoid mutual interference, as in SU-COMP. However, for the forward link transmission, the transmitter needs to know all channel state information (CSI), which is impractical to implement.

**[0006]** SU-COMP techniques and MU-COMP techniques employ different approaches to reduce mutual interference among users – SU-COMP uses RRM to separate users and MU-COMP uses signal processing based on CSI. The RRM approach is inefficient, while full knowledge of CSI makes the signal processing approach impractical.

## SUMMARY

**[0007]** According to one or more embodiments of the present invention, user grouping is employed to tradeoff the COMP forward link capacity and required reverse link feedback, which makes the design of COMP practical and flexible. The network transmits reference

signals from at least two geographically distributed transmit antennas. A channel element, such as the large scale fading, is measured for each distributed transmitter and UE pair, and the network receives this information as feedback in the reverse link. The COMP determines a maximum cross interference level  $\alpha_{req}$  that can be supported, based on the available reverse link capacity for feedback. If this maximum cross interference level  $\alpha_{req}$  is exceeded, geographically separate UEs are divided into as few groups as possible, and the groups are allocated different time/frequency resource blocks. The grouping is done with the constraint that the cross interference does not exceed  $\alpha_{req}$ .

**[0008]** With sufficient reverse link capacity, the COMP can increase forward link capacity by grouping more users together, with less separation between users in a group. When the reverse link capacity is constrained, the separation of users in each group is increased by creating more, smaller groups. In this case, all users' QoS can be satisfied, at the cost of some loss in the overall system capacity.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** Figure 1 is a functional block diagram of a COMP forward link.

**[0010]** Figure 2 is a graph plotting capacity vs. SNR for various feedback schemes for a COMP with cross interference of 0.2.

**[0011]** Figure 3 is a graph plotting capacity vs. SNR for various feedback schemes for a COMP with cross interference of 0.1.

**[0012]** Figure 4 is a graph plotting capacity vs. SNR for various feedback schemes for a COMP with cross interference of 0.05.

**[0013]** Figure 5 is a flow diagram of a method of grouping COMP users.

**[0014]** Figure 6 is a diagram of the distribution of users in a COMP.

**DETAILED DESCRIPTION**

**[0015]** Figure 1 depicts a functional block diagram of an exemplary COMP wireless communication network 10. A controller 12 weights signals transmitted by each of at least two geographically distributed transmit antennas 14, 16. Signals from each antenna 14, 16 are received by each of at least two User Equipment (UE) 18, 20 in the operative area, or cell. Because both the transmit antennas 14, 16 and the UEs 18, 20 are geographically dispersed, in general, each UE 18, 20 will not receive signals from each transmit antenna 14, 16 with the same signal strength. Rather, due to path loss, signals transmitted by a closer antenna 14, 16 will be received strongly, and signals transmitted by a further antenna 14, 16 will be received weakly.

**[0016]** Cross interference is defined for a UE 18, 20 as the squared ratio of the channel variances of an interfering (i.e., more distant) antenna to that of a desired (i.e., closer) antenna. The performance of the COMP network depicted in Figure 1 – with two distributed antennas 14, 16 and two single-antenna UEs 18, 20 – was simulated. In the simulation, it was assumed  $E(|h_{1,1}|^2) = E(|h_{2,2}|^2) = 1$ ,  $E(|h_{1,2}|^2) = E(|h_{2,1}|^2) = \alpha^2$ , where  $\alpha \leq 1$  represents the cross interference.

**[0017]** Copending patent application serial no. \_\_\_\_, titled “MU-COMP Channel State Ratio Quantization and Transmission,” assigned to assignee of the present application and incorporated herein by reference in its entirety, describes a technique to reduce the reverse link overhead load caused by UEs reporting, or feeding back, CSI in MU-COMP. Briefly, the technique exploits the fact that interfering channels generally have a much lower signal strength than desired channels. Thus, the ratio of an element of the channel state, such as fast fading, of an interfering channel to a desired channel will be small, and can be quantized into only a small number of bits  $q$ . In particular, the ratio is modeled as a ratio of complex

Gaussian random variables with unit variance. The ratio is quantized separately in amplitude and phase, into values of bit length  $q_1$  and  $q_2$ .

**[0018]** Figure 2 depicts the simulation results for a cross interference of 0.2; Figure 3 depicts the simulation results for a cross interference of 0.1; and Figure 4 depicts the simulation results for a cross interference of 0.05. The graphs plot capacity as a function of SNR for different amounts of feedback – no feedback,  $q_1=q_2=2$ ,  $q_1=q_2=5$ , and full CSI – for the specified cross interference level.

**[0019]** Assume users have a QoS requirement of 6 bits/s/Hz in capacity at a SNR of 30 dB. From Figures 2, 3, and 4, one observes that this requirement can be satisfied with  $q_1=q_2=5$  when the cross interference is 0.2,  $q_1=q_2=2$  when the cross interference is 0.1; and no feedback is needed when the cross interference is 0.05.

**[0020]** The results reveal that when the cross interference is large, such as when a user is close to an interfering antenna, more channel state feedback information is needed. On the other hand, when the cross interference is small, such as when a user is some distance from any interfering antenna, the amount of the required feedback information is smaller.

**[0021]** According to one or more embodiments of the present invention, the cross interference is controlled by user selection and grouping. Users in the same group use the same time/frequency resource (or resource block), and are hence geographically separated, preferably by at least a reuse pattern distance, to maintain the cross interference below a desired level. Different groups use different resource blocks. Accordingly, users close together but in different groups do not experience cross interference.

**[0022]** Figure 5 depicts a flow diagram of a method 100 of user selection and grouping. While those of skill in the art will recognize that the method 100 is ongoing continuously, for the purpose of explanation, the method 100 “begins” by transmitting reference signals from at least two geographically distributed transmit antennas 14, 16 (block 102). A channel element,

such as the large scale fading, is measured for each distributed transmitter 14, 16 and UE 18, 20 pair, and the network receives this information as feedback in the reverse link (block 104). The COMP determines a maximum cross interference level  $\alpha_{req}$  that can be supported, based on the available reverse link capacity for feedback (block 106). If this maximum cross interference level  $\alpha_{req}$  is exceeded (block 108), geographically separate UEs 18, 20 are divided into as few groups as possible, and the groups are allocated different resource blocks (block 110). The grouping is done with the constraint that the cross interference does not exceed  $\alpha_{req}$ . This grouping method can be formulated into the following mathematic form: Find an optimal partition for users indexed  $1, 2, 3, \dots, K$   $S_{opt} = \arg \min_S (\#S)$ , where  $S = \{S_1, S_2, \dots\}$  is any possible partition such that for any set  $S_i \subset S$ ,  $\alpha_{m,n} \leq \alpha_{req}$  is satisfied for  $m, n \in S_i, m \neq n$ .  $\alpha_{m,n} \leq \alpha_{req}$  is the cross interference level between user  $m$  and user  $n$ . An exhaustive search for the optimal partition is always possible, although the complexity grows at least exponentially with the number of nodes involved. The system then continues to monitor performance (block 102).

**[0023]** Figure 6 depicts a representative distribution of users 1-8 and transmitting antennas in a COMP. When the reverse link capacity is sufficient to support a high level of channel state feedback, the users are divided into two groups  $\{1, 3, 5, 7\}$  and  $\{2, 4, 6, 8\}$ , and each group is allocated different resource blocks. The users in each group are sufficiently geographically dispersed that they do not interfere with each other. In this case, each resource block allocated can support four users simultaneously, and the capacity is relatively large. When less feedback can be supported due to reverse link capacity constraints, these users are divided into four groups  $\{1, 7\}$ ,  $\{2, 8\}$ ,  $\{3, 5\}$ , and  $\{4, 6\}$ . Again, the users in each group are separated from each other, and each group is allocated a different resource block. With this



grouping, all users' QoS can be satisfied. However, each resource block only supports two users simultaneously, hence the overall system capacity decreases.

**[0024]** Embodiments of the present invention provide a user grouping method to tradeoff the COMP forward link capacity and required reverse link feedback, which makes the design of COMP practical and flexible. In particular, flexibility is introduced in at least two respects. First, with increased reverse link capacity that can support more channel state feedback, the separation of users in the same group can be decreased. Thus, more users can be included in each group and the system capacity is increased. Second, when the reverse link capacity is constrained, the separation of users in each group is increased. In this case, all users' QoS can be satisfied, at the cost of some loss in the overall system capacity.

**[0025]** The present invention may, of course, be carried out in other ways than those specifically set forth herein without departing from essential characteristics of the invention. The present embodiments are to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

**CLAIMS**

1. A method (100) of operating a transmitter in a Multi-User Distributed Antenna System (MU-COMP) wireless communication network (10) comprising at least two geographically distributed transmitters (14, 16) and in which at least two User Equipments (UE) (18, 20) are receiving signals, comprising:
  - transmitting reference signals from each transmitter (14, 16);
  - receiving from each UE (18, 20) feedback information about the forward link channel state, calculated by the UE (18, 20) from received reference signals; and
  - grouping UEs (18, 20) and allocating time/frequency resources on a per-group basis, based on reverse link capacity.
2. The method (100) of claim 1 wherein grouping UEs (18, 20) comprises determining a maximum cross interference level based on users' quality of service requirement and reverse link capacity, and grouping the UEs (18, 20) such that the determined maximum cross interference level is not exceeded.
3. The method (100) of claim 3 wherein grouping the UEs (18, 20) such that the determined maximum cross interference level is not exceeded comprises forming the fewest groups possible that do not exceed the determined maximum cross interference level.
4. The method (100) of claim 1 wherein the UEs in each group are as geographically separated as a time/frequency resource reuse pattern distance.
5. The method (100) of claim 1 wherein the feedback information about the forward link channel state comprises a quantized measure of the ratio of channel elements for a channel

relatively weakly received by a UE (18, 20) from a first transmitter (14, 16) to that for a channel relatively strongly received by the UE (18, 20) from a second transmitter (14, 16).

6. A transmitter (14, 16) in a Multi-User Distributed Antenna System (MU-COMP) wireless communication network (10), including at least two geographically distributed transmitters (14, 16), each transmitting reference signals, the transmitter (14, 16) comprising a controller (12) operative to receive feedback information regarding the forward link channel state from at least two User Equipment (UE) (18, 20) and further operative to group the UEs (18, 20) and allocate time/frequency resources on a per-group basis, based on reverse link capacity;

7. The transmitter (14, 16) of claim 7 wherein the controller (12) is further operative to group the UEs (18, 20) based also on the reverse link capacity.

8. The transmitter (14, 16) of claim 8 wherein the controller (12) is further operative to determine a maximum cross interference level based on users' quality of service requirement and reverse link capacity, and to group the UEs (18, 20) such that the determined maximum cross interference level is not exceeded.

9. The transmitter (14, 16) of claim 9 wherein the controller (12) is further operative to form the fewest groups possible that do not exceed the determined maximum cross interference level.

10. The transmitter (14, 16) of claim 7 wherein the UEs (18, 20) in each group are as geographically separated as a time/frequency resource reuse pattern distance.

11. The transmitter (14, 16) of claim 7 wherein the feedback information about the reverse link channel quality comprises a quantized measure of the ratio of channel elements for a channel relatively weakly received by a UE (18, 20) from a first transmitter (14, 16) to that for a channel relatively strongly received by the UE (18, 20) from a second transmitter (14, 16).

1/6

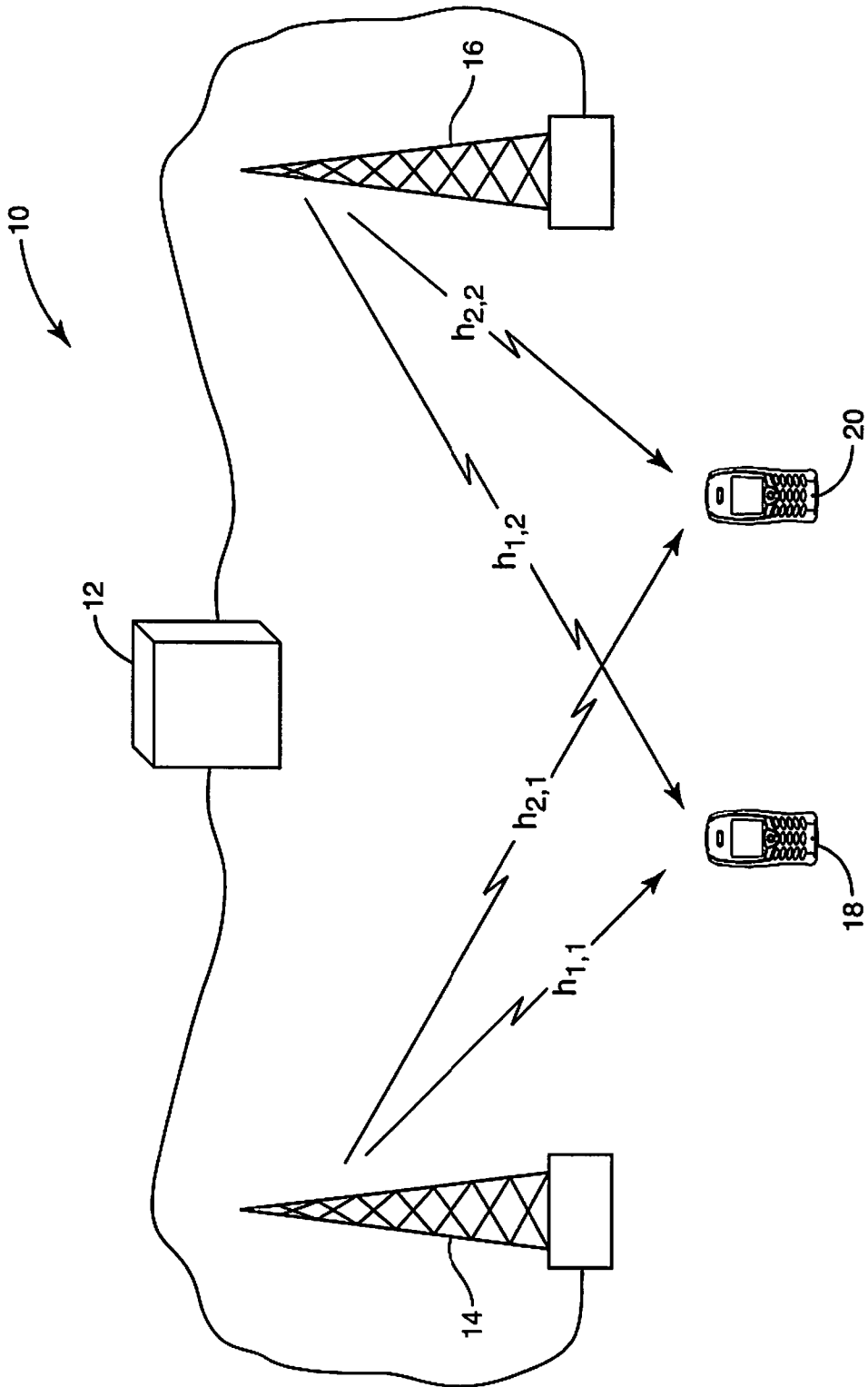
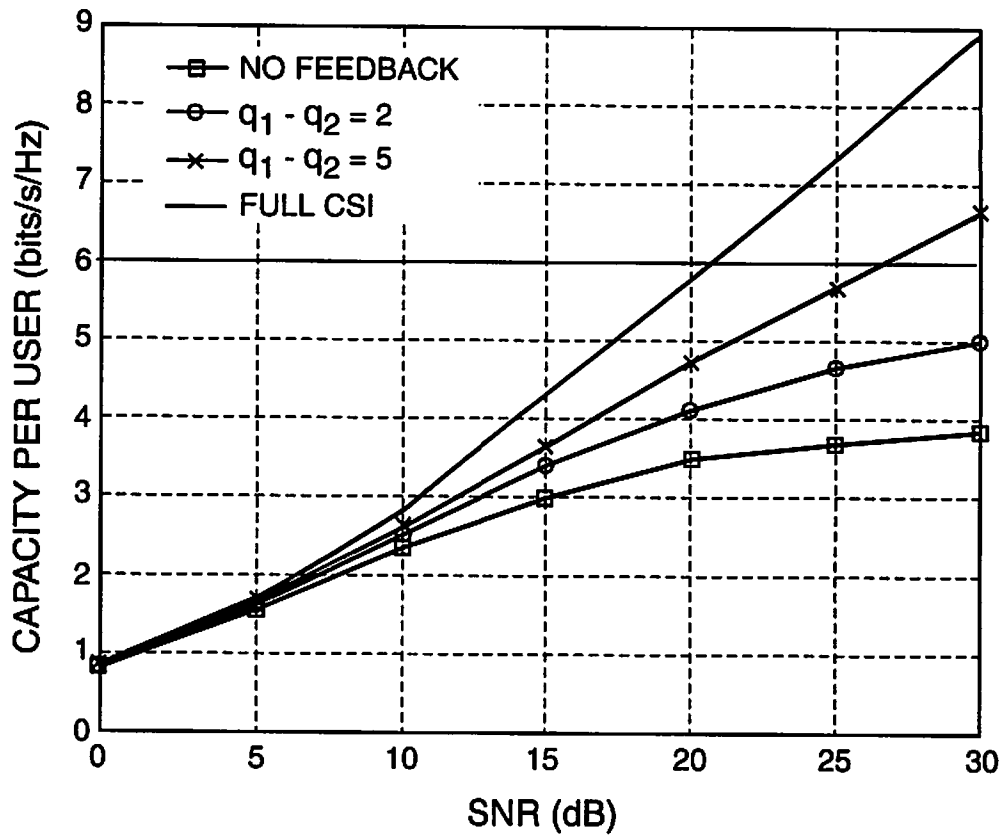


FIG. 1



**FIG. 2**

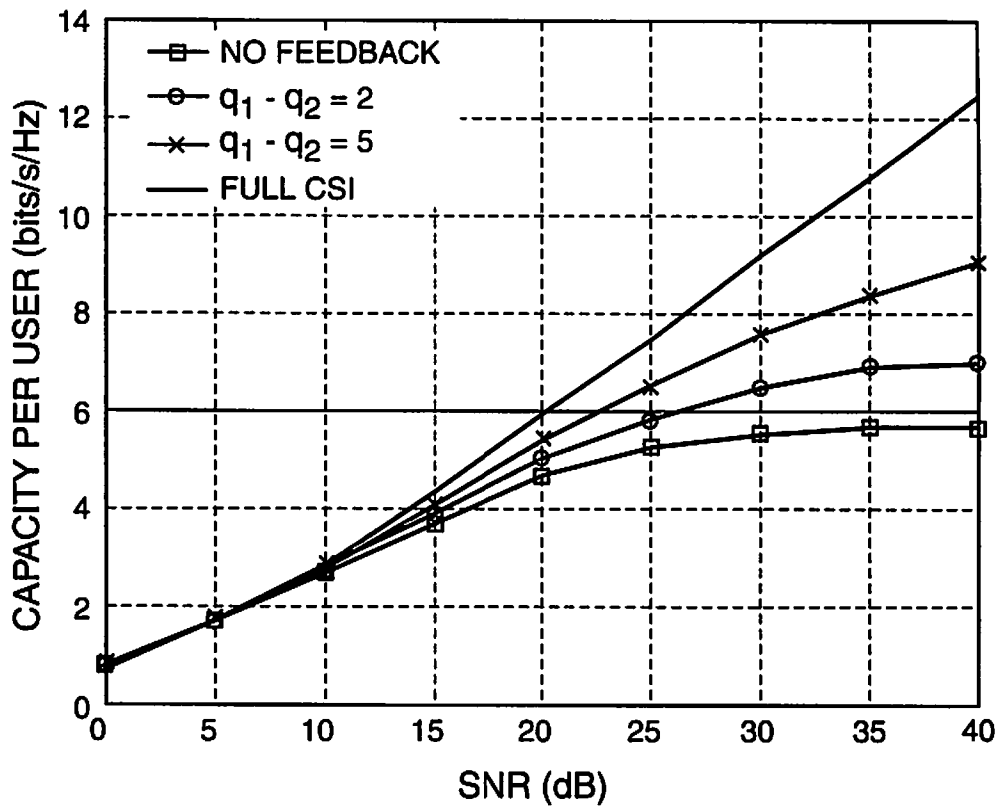
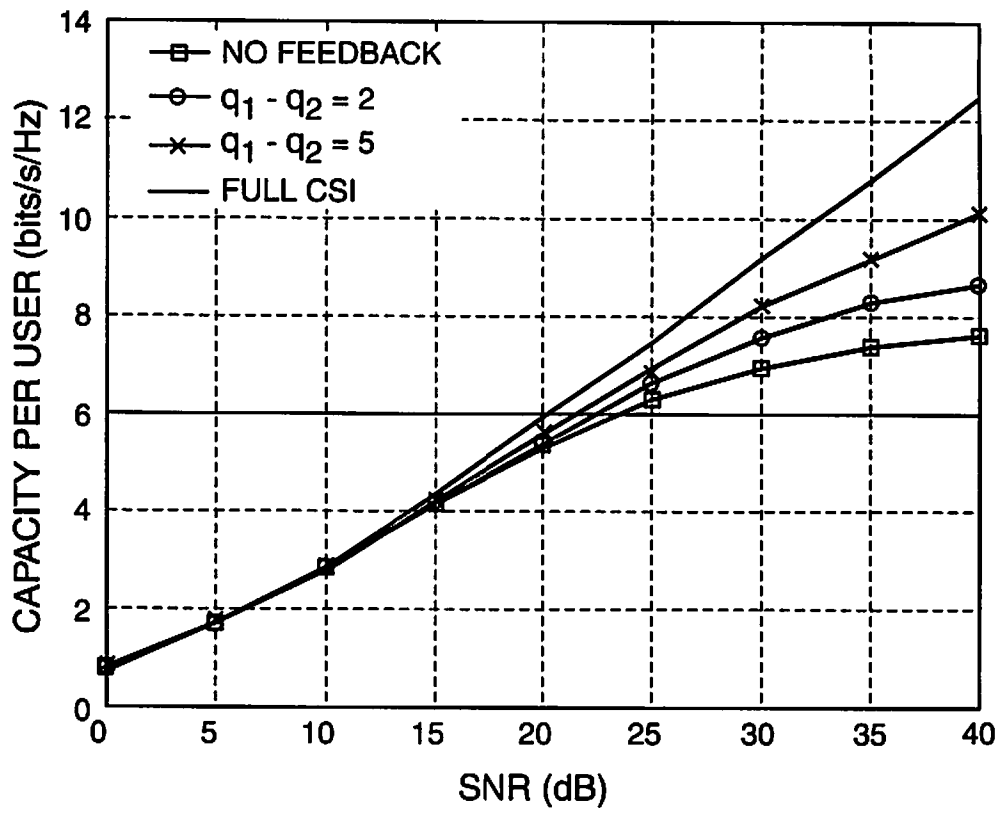


FIG. 3



**FIG. 4**



5/6

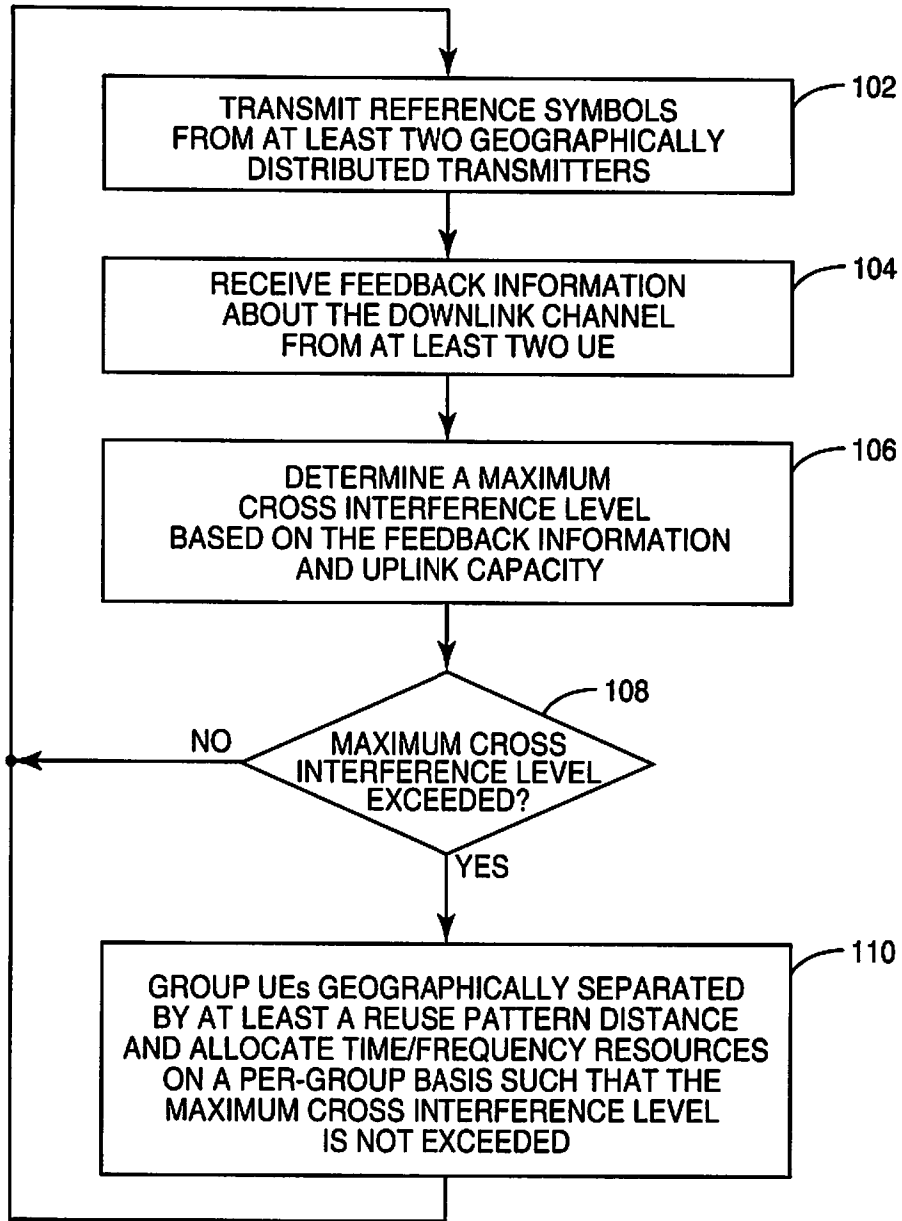
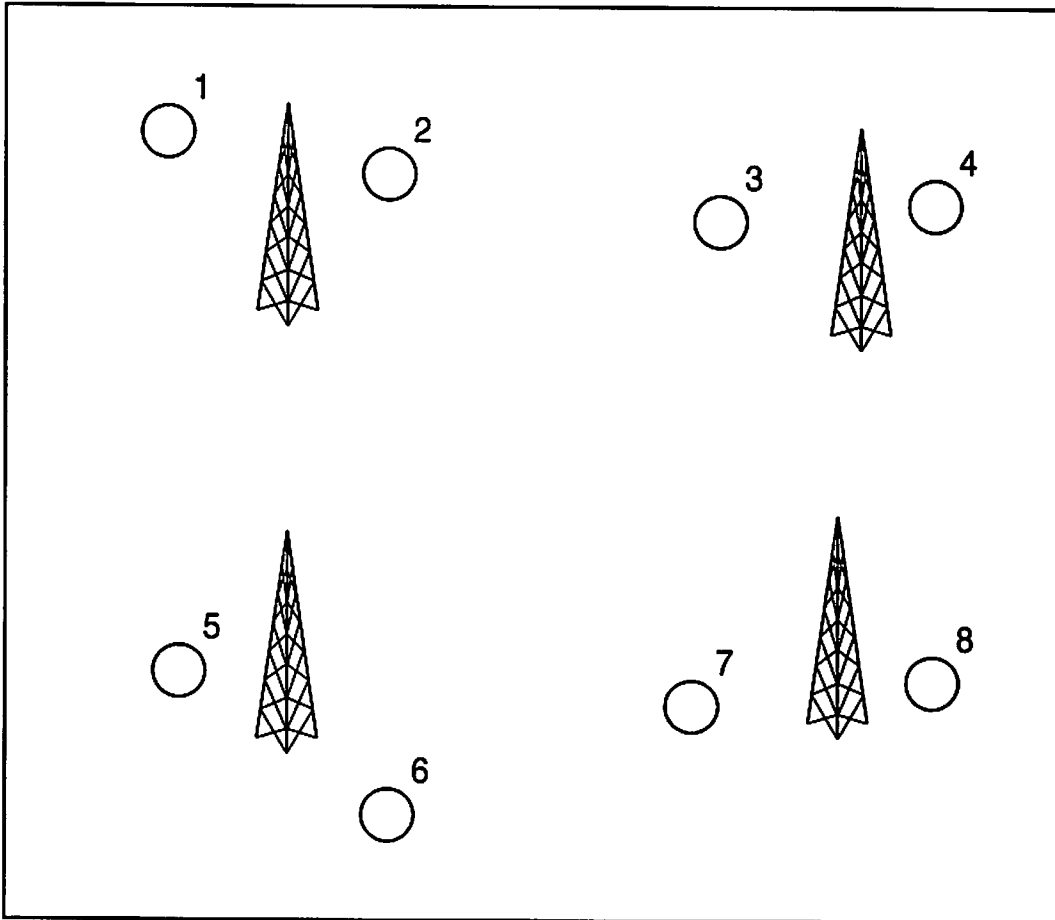


FIG. 5



**FIG. 6**

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/SE2008/051070

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. H04W72/08

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)  
H04W

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

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

EPO-Internal, WPI Data, INSPEC, COMPENDEX

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>SAMSUNG: "Inter-Cell Interference Mitigation Through Limited Coordination" 3GPP DRAFT; R1-082886 INTER-CELL INTERFERENCE MITIGATION THROUGH LIMITED COORDINATION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Jeju; 20080818, 18 August 2008 (2008-08-18), XP050316366 [retrieved on 2008-08-12] page 1, paragraph 1 - page 2, paragraph 1 page 4, paragraph 4.1 - page 7, paragraph 4.2 figures 1,2,6</p> <p style="text-align: center;">----- -/--</p>	1-11

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

\*A\* document defining the general state of the art which is not considered to be of particular relevance

\*E\* earlier document but published on or after the international filing date

\*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

\*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

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\* & \* document member of the same patent family

Date of the actual completion of the international search

17 June 2009

Date of mailing of the international search report

08/07/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Rosenauer, Hubert

INTERNATIONAL SEARCH REPORT

International application No  
PCT/SE2008/051070

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>MAHESH VEMULA ET AL: "Inter-Cell Coordination, Opportunistic Beamforming and Scheduling" COMMUNICATIONS, 2006. ICC '06. IEEE INTERNATIONAL CONFERENCE ON, IEEE, PI, 1 June 2006 (2006-06-01), pages 5319-5324, XP031025760 ISBN: 978-1-4244-0354-7 abstract page 5322, paragraph C - page 5323, paragraph D</p>	1-11
A	<p>ERICSSON: "LTE-Advanced - Coordinated Multipoint transmission/reception" 3GPP DRAFT; R1-083069 {COMP}, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Jeju; 20080818, 18 August 2008 (2008-08-18), XP050316512 [retrieved on 2008-08-13] the whole document</p>	1-11
A	<p>FUJITSU: "Discussion on DL coordinated multipoint transmission" 3GPP DRAFT; R1-083115, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Jeju; 20080818, 18 August 2008 (2008-08-18), XP050316556 [retrieved on 2008-08-13] page 1, paragraph 1 - paragraph 2 page 5, paragraph 2.4 - page 6, paragraph 3 figures 5,6</p>	1-11
A	<p>ETRI: "Frame Structure to Support Inter-cell Interference Mitigation for Downlink Traffic Channel using Co-MIMO and FFR" IEEE 802.16M-08/017, [Online] 16 January 2008 (2008-01-16), pages 1-8, XP002532561 Retrieved from the Internet: URL:<a href="http://grouper.ieee.org/groups/802/16/tgm/contrib/C80216m-08_017.pdf">http://grouper.ieee.org/groups/802/16/tgm/contrib/C80216m-08_017.pdf</a> [retrieved on 2009-06-16] page 5 - page 6 figures 3,4</p>	1-11

## INTERNATIONAL SEARCH REPORT

international application No

PCT/SE2008/051070

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>NXP SEMICONDUCTORS ET AL: "Feedback and Precoding Techniques for MU-MIMO for LTE-A" 3GPP DRAFT; R1-083244, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, no. Jeju; 20080818, 18 August 2008 (2008-08-18), XP050316656 [retrieved on 2008-08-13] page 1, paragraph 1 page 6, paragraph 5.3 - page 7, paragraph 5.3</p> <p style="text-align: center;">-----</p>	1-11