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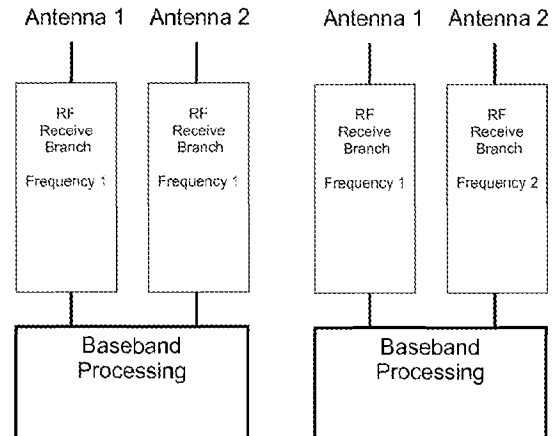
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**GB 2448481 A** **WO 2009/132203 A1**  
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(54) Title of the Invention: **Adaptive use of multiple receiver chains**  
Abstract Title: **A multi-antenna receiver is switched between receiver diversity mode and carrier aggregation mode on the basis of network or/and terminal parameters**

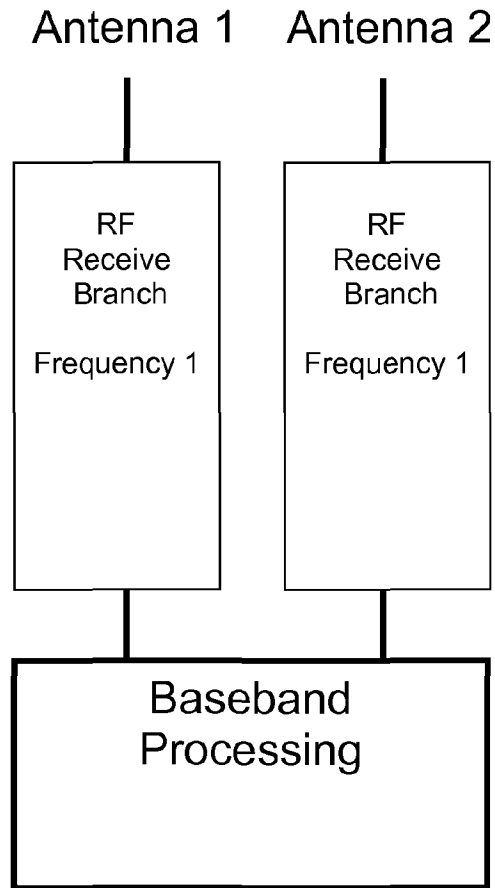
(57) A multi-antenna receiving terminal can be switched between a receiver diversity mode (Fig. 1), in which the same data is received at each of a plurality of different antenna, and a carrier aggregation mode (Fig.2). In the carrier aggregation mode data has data been multiplexed across multiple carrier frequencies and each carrier is received by a different respective antenna. A network element (e.g.eNodeB) decides whether to switch between modes based on a network parameter, such as load, or a channel quality indication and instructs the receiving terminal accordingly. Carrier aggregation mode is also known as spectrum aggregation mode, dual carrier mode and dual cell mode.



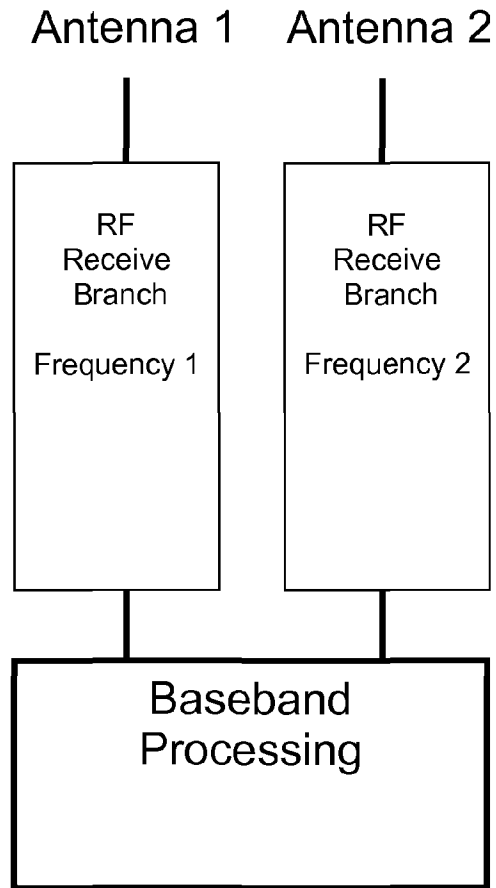
**Fig 1**

**Fig 2**

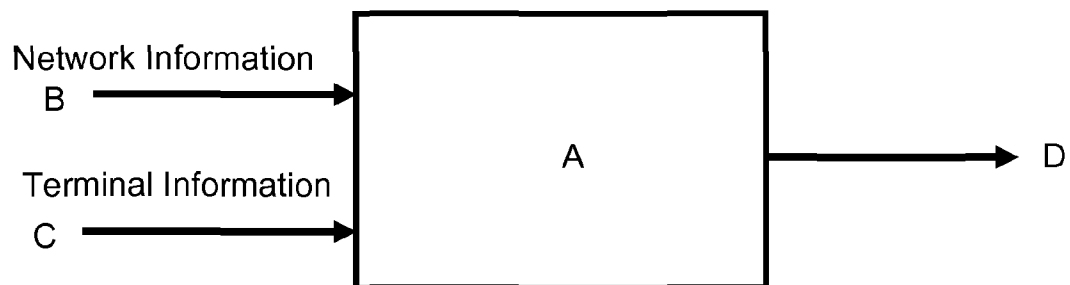
**GB 2472978 A**



**Fig 1**



***Fig 2***



***Fig 3***

## ADAPTIVE USE OF MULTIPLE RECEIVER CHAINS

The present invention relates to a system using multiple receiver chains adaptively to increase cellular telecommunications network capacity at different load levels. In particular, the invention increases the data throughput supported by a mobile broadband terminal and increases the capacity of the supporting network.

A known technique for increasing the capacity of a cellular telecommunications network such as HSDPA, LTE, WiFi or WiMAX is to bond together two parallel carriers. This approach is called carrier or spectrum aggregation.

The conventional solution to implement carrier aggregation would be to duplicate the entire receiver hardware, or substantial parts of it, with substantial added cost.

High performance receivers already have duplicated hardware with two parallel receiver chains. These are currently used to implement another well known technique called receiver diversity. Receiver diversity can itself substantially increase the throughput of a terminal and the capacity of the associated network.

HSDPA (High Speed Downlink Packet Access) is a packet-based data service in the 3rd generation W-CDMA (Wideband Code Division Multiple Access) systems, which provides high-speed data transmission (with different theoretical peak download rates according to the HSDPA technology step e.g. 7.2/10.8/16.2/21.6/28.8/42 Mbps over a 5MHz bandwidth) to support multimedia services.

In order to reach higher theoretical peak rates (28.8 Mbps with 3GPP Release 7 or 42 Mbps with Release 8), the MIMO (Multiple Input Multiple Output) feature is used in HSDPA, in which multiple antennas are implemented at both base station (Node B) and mobile terminals (UE: User Equipment). As mobile terminal hardware implementing the MIMO feature is provided with two parallel receiver chains, MIMO may be considered a variety of receive diversity.

The basic MIMO feature as standardised in 3GPP Release 7 requires (just) two transmitter antennas (at the node B) and two receiving antennas (at the UE) using a common carrier. At the transmitter, the transmitted data is divided into two data streams and transmitted through the two antennas using the same radio resource (same time i.e. Transmission Time Interval (TTI) and HSDPA codes). The two streams of data are recovered by the UE from the signals received via its two antennas. Clearly then, the MIMO feature needs support in MIMO-enabled terminals as well as in the network.

In order to deploy MIMO at the node B and to transmit two parallel data streams, two power amplifiers are required per sector (one for each of the two antennas). In order not to limit the use an entire carrier for MIMO only (5MHz), it is more efficient and practical to use the same carrier as devices that are not MIMO-enabled (e.g. HSDPA legacy terminals) to utilise all available capacity.

MIMO technology is an important step in the evolution of HSDPA, as it provides higher data rates in downlink whilst further improving spectrum efficiency.

Receive diversity is not limited to the use of *two* parallel receive paths: the same feature can be implemented in hardware having three or more antennas. Furthermore, where three or more antennas are available it is entirely possible that only a subset of the available antennas be used to provide parallel receive paths at  
5 any given time.

In the context of implementing carrier or spectrum aggregation using terminals readied for MIMO technology, it has previously been suggested that the second receiver, which was originally designed to allow receive diversity/MIMO,  
10 could be redeployed and tuned to a different channel instead, to implement carrier aggregation. A major disadvantage in taking this approach would be the complete loss of the receive diversity/MIMO gain.

In accordance with one aspect of the present invention, there is provided a  
15 network element in a cellular telecommunications network for increasing network capacity, the network including at least one mobile data terminal equipped with a plurality of receivers, the terminal being operable to communicate with the network element in a receiver diversity mode and in a carrier aggregation mode, the network element including: a decision making unit that instructs the terminal to  
20 switch from receiver diversity mode to carrier aggregation mode in dependence upon at least one input parameter.

The network element is typically an eNode B or base station but could also be another element such as an Access Gateway.

25

As will be apparent from the preceding discussion, where the terminal hardware has three or more antennas, there will be further options in addition to all available antennas being switched from receiver diversity mode to carrier

aggregation mode. Consider a scenario where there are four antennas in the terminal – two of the four antennas may be switched to carrier aggregation mode while the remaining two may be left in receiver diversity mode. The invention is nonetheless implemented for at least a subset of the receiver antennas at the terminal.

It is preferred that one or more of the at least one input parameters is a *network* parameter. In particular, the at least one input parameter may correspond to a measured network load level at the network element; and the switching instruction may then be transmitted when the load level is calculated to be below a first predetermined threshold value.

In this aspect, the invention takes advantage of the fact that carrier aggregation offers its greatest advantage under different circumstances from receive diversity or MIMO. In particular, the advantage of carrier aggregation is greatest at lower load levels. The performance of the network can be maximised by adaptively deploying the receivers in each mobile data terminal according to the traffic load in the network and the channel conditions between the terminal and the network.

The invention therefore provides an adaptive system in which the network instructs terminals that are equipped with two or more receivers to operate in a “spectrum/carrier aggregation mode” provided the load level in a given cell or sector is calculated to be below a first predetermined threshold value.

In the event of heavy loading of the system (i.e. substantially above the first threshold value for a significant time), the network element (for example the eNodeB) instructs those multiple receiver terminals to redeploy their second



receiver on to the same channel as the first and to switch to a “receiver diversity mode”.

Likewise, in the event of a change from heavy to light loading of the system  
5 (i.e. substantially below a second threshold value for a significant time), the network element (i.e the eNodeB) instructs those multiple receiver terminals to switch to “carrier aggregation mode”.

In addition or alternatively, one or more of the at least one input parameters  
10 may be a terminal parameter.

Preferably, the mode determined by the network may further be determined by the channel quality indication reported by the terminal. Additionally or alternatively, the mode determined by the network may be determined by the  
15 estimation of the diversity gain of the terminal.

The mode determined by the network be determined may additionally or alternatively be determined by the characteristics of the data traffic.

20 In accordance with another aspect of the present invention, there is provided a method of operating a cellular telecommunications network to increase network capacity, the network including at least one mobile data terminal equipped with a plurality of receivers, the terminal being operable to communicate with the network element in a receiver diversity mode and in a carrier aggregation mode,  
25 the method including: obtaining at least one input parameter; and instructing the terminal to switch from receiver diversity mode to carrier aggregation mode in dependence upon said at least one input parameter.

The carriers aggregated in carrier aggregation mode are preferably two or more *consecutive* carriers within one frequency band. Alternatively these carriers may be *non-consecutive* carriers within one frequency band.

5        Optionally, the aggregated in carrier aggregation mode are preferably *non-consecutive* carriers within *two or more frequency bands*.

The cellular telecommunications network may operate in either paired or unpaired spectrum allocations.

10

The cellular telecommunications network preferably uses a bearer technology selected from the following technologies: OFDM, OFDMA or CDMA.

15        As mobile terminals are already being deployed with more than one receiver paths in order to operate with receive diversity or MIMO modes, these multiple receiver paths may be suitable for operating the invention, the invention also reduces the cost of implementing a receiver capable of carrier aggregation.

20        It is an object of the invention to obviate or at least mitigate the above problems.

For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings in which:-

25        Figure 1 shows a receiver arrangement in the receive diversity mode;  
Figure 2 shows a receiver arrangement in the carrier aggregation mode; and  
Figure 3 illustrates diagrammatically the operation of a decision making unit as required in the present invention.

Figure 1 shows an example implementation of the invention with a diversity/MIMO configuration with two RF receive branches and two antennas which operate at the same frequency. The baseband processing is common for both receive branches. The receive branches may be implemented physically separated or within a single chip.

Figure 2 shows the hardware of Figure 1 in the carrier aggregation configuration where the two receive branches operate at different frequencies. In this case, different antennas may be used, or alternatively both RF receive branches connect to the same antenna.

Figure 3 shows a decision making unit A. It will be provided with input parameters B from the network, such as load or scheduling constraints. B denotes input parameters from the network (such as the network load), while C denotes input parameters from the terminal such as CQI, SNR, SNIR, BLER, correlation, frequency diversity, battery state. The decision on terminal configuration D is then conveyed to the terminal.

In an example embodiment of the invention, a decision making unit or procedure is deployed within the network (i.e. within the eNodeB). One way to implement such a decision making unit is as part of the scheduler. The decision making unit can have as objectives to optimize the throughput of the individual terminal or the aggregate throughput of the cell.

The decision making unit applies an appropriate hysteresis in order to prevent oscillations between different terminal configuration states.

Also, the input data to the decision metric has to be averaged in an appropriate manner, especially over time. If a terminal is only for a short period of

time in a signal condition where diversity would be more appropriate than carrier aggregation (i.e. when it is fast driving in a vehicle), switching the terminal configuration should not be done. Therefore, the decision making unit has to estimate the stability of a certain signal condition. One possible means to do this is  
 5 sliding window averaging.

Examples of suitable input parameters for the decision making unit include: the network load; the CQI values (channel quality indicators); terminal SNR (signal to noise rate) or SNIR (signal to noise and interference ratio) prediction; the  
 10 Block Error Rate (BLER); the precoding index determined by the terminal; the correlation between the receiver branches; the frequency diversity across the candidate bands for aggregation.

Further optional input to the decision unit may include data corresponding to  
 15 the characteristics of the data traffic for a specific terminal. Such data may be obtained either by using Quality of Service (QoS) classes or by traffic class estimation by the network, i.e. deep packet inspection or by statistical analysis of the traffic.

20 It is well-known that carrier aggregation has more benefits for bursty data traffic (such as web-browsing). A simple estimation of the burstiness or the index of the predominant traffic class may be used as a further input to the decision making unit.

25 As the reader will appreciate the decision making unit does not require *all* of the above input parameters to be present – the decision upon when or whether a particular input parameter is to be use may be determined by the degree of effort

needed to obtain the values and the effectiveness for the decision making for the specific communications network implementation.

In an alternative embodiment, the decision whether to instruct the use of either carrier aggregation mode or receiver diversity mode also takes into account the power consumption of both modes and/or the current battery state of the terminal. The power consumption estimates of both methods are either stored in a look-up table or are measured within the terminal. When power consumption is critical (i.e. the battery is low), the more power efficient method is preferred – this may be effect by the application of a weighting/correction term in the decision metric.

In a further embodiment, the decision to switch between receive diversity mode and carrier aggregation mode is made by the terminal, with assistance from the network.

The preceding discussion concentrates on the benefits of the invention for mobile terminals that are in power limited but not necessary code limited conditions. In this discussion, it is also assumed that the first carrier is on a higher frequency band than the second frequency band with which the first band is to be aggregated. In both cases, the assumptions need not hold for the invention to be implemented.

When switching to carrier aggregation mode, the scheduler needs to set an appropriate transport block size for communications on the second (newly switched to) carrier. The transport block size may be determined by making an estimated adjustment based on pathloss/frequency band. If it is assumed that the

second carrier is less loaded than the first the transport block size can always be set to be at least equal to the block size on the first carrier.

Throughout this document, the term "receive diversity" is to be understood  
5 to encompass both receive diversity and related technologies, such as MIMO.

**CLAIMS:**

1. A network element in a cellular telecommunications network for increasing network capacity, the network including at least one mobile data terminal equipped with a plurality of receivers, the terminal being operable to communicate with the  
5 network element in a receiver diversity mode and in a carrier aggregation mode,  
the network element including:  
a decision making unit that instructs the terminal to switch from receiver diversity mode to carrier aggregation mode in dependence upon at least one input parameter.  
10
2. A network element as claimed in claim 1, wherein one or more of the at least one input parameters is a network parameter.
3. A network element as claimed in claim 2, wherein the at least one input  
15 parameter corresponds to a measured network load level at the network element; and wherein the switching instruction is transmitted when the load level is calculated to be below a first predetermined threshold value.
4. A network element as claimed in any one of claims 1 to 3, wherein one or  
20 more of the at least one input parameters is a terminal parameter.
5. A network element as claimed in claim 4, wherein at least one of the input parameters is the channel quality indication reported by the terminal.
- 25 6. A network element as claimed in claim 4 or claim 5, wherein at least one of the input parameters is an estimation of the diversity gain of the terminal.

7. A network element as claimed in any one of claims 4 to 6, wherein at least one of the input parameters is a metric characteristic of the data traffic.

8. A method of operating a cellular telecommunications network to increase network capacity, the network including at least one mobile data terminal equipped with a plurality of receivers, the terminal being operable to communicate with the network element in a receiver diversity mode and in a carrier aggregation mode, the method including:

obtaining at least one input parameter; and

instructing the terminal to switch from receiver diversity mode to carrier aggregation mode in dependence upon said at least one input parameter.

9. A method as claimed in claim 8, wherein one or more of the at least one input parameters is a network parameter.

10. A method as claimed in claim 9, wherein the at least one input parameter corresponds to a measured network load level at the network element; and wherein the switching instruction is transmitted when the load level is calculated to be below a first predetermined threshold value.

11. A method as claimed in any one of claims 8 to 10, wherein one or more of the at least one input parameters is a terminal parameter.

12. A method as claimed in claim 11, wherein at least one of the input parameters is the channel quality indication reported by the terminal.

13. A method as claimed in claim 11 or claim 12, wherein at least one of the input parameters is an estimation of the diversity gain of the terminal.



14. A method as claimed in any one of claims 11 to 13, wherein at least one of the input parameters is a metric characteristic of the data traffic.

5 15. A network element as hereinbefore described with reference to the aforementioned drawings.

16. A method as hereinbefore described with reference to the aforementioned drawings.

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**Application No:** GB0914716.6

**Examiner:** Dr John Cullen

**Claims searched:** 1-16

**Date of search:** 18 November 2009

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3 and 8-10	US2006/0221894 A1 (CASACCIA) See Abstract, Fig. 1 and para. 26.
X	1-3 and 8-10	"3GPP TR 45.192 V7.0.0; Feasibility study for evolved GSM/EDGE Radio Access Network (GERAN) (Release 7)", 12 Oct 2006. Downloaded from <a href="http://www.3gpp.org/ftp/Specs/html-info/45912.htm">http://www.3gpp.org/ftp/Specs/html-info/45912.htm</a> on 18 Nov 2009. See pages 391 and 392
X,E	1-3 and 8-10	WO2009/132203 A1 (INTERDIGITAL) See paragraph 13.
X	1 and 8 at least	GB2448481 A (SIEMENS) See the Abstract, Figs. 1 and 2 and claim 12.
X	1-3 and 8-10	C. GESSNER: "T&M Requirements for Mobile Radios with Receive Diversity and Advanced Receivers", May 2006, RHODE & SCHWARZ Application Note 1MA88. Downloaded from <a href="http://www.shop.rohde-schwarz.com/www/downcent.nsf/ANFileByANNoForInternet/3D7728599C7BEECDC1257178003C8BF9/\$file/1MA88_0e.pdf">http://www.shop.rohde-schwarz.com/www/downcent.nsf/ANFileByANNoForInternet/3D7728599C7BEECDC1257178003C8BF9/\$file/1MA88_0e.pdf</a> on 18/11/09 See pages 10 and 11

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup>:

Worldwide search of patent documents classified in the following areas of the IPC

H04B; H04L

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC, TXTE, TXTT, INSPEC, XPI3E, XPIEE, XPESP, INTERNET



**International Classification:**

<b>Subclass</b>	<b>Subgroup</b>	<b>Valid From</b>
H04B	0007/08	01/01/2006
H04L	0001/00	01/01/2006
H04L	0027/26	01/01/2006