Title: METHOD AND APPARATUS FOR ANTENNA AND TRANSMISSION MODE SWITCHING

Abstract: A method and apparatus for antenna and transmission mode switching of a wireless communication channel, the method comprising the steps of: calculating a switching criterion; selecting a transmission mode on the basis of said switching criterion; and selecting a respective antenna system in response to said selected transmission mode.
Method and Apparatus for Antenna and Transmission Mode Switching

FIELD OF THE INVENTION

[0001] The present invention relates to wireless communication systems and in particular to transition mode switching of wireless communication systems.

[0002] The invention has been developed primarily for antenna and transmission mode switching and will be described hereafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND OF THE INVENTION

[0003] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of the common general knowledge in the field.

[0004] Multiple-input multiple-output (MIMO) transmission is a scheme for achieving high data rates in next generation wireless communication system. It will be appreciated that, typical MIMO channels experience correlation. It will be further appreciated that beamforming (BF) can outperform spatial multiplexing (SM) in highly correlated MIMO channels, such as LOS channels.

[0005] Transmission mode switching between spatial multiplexing and beamforming has been used to enhance spectral efficiency by exploiting spatially correlated MIMO channels. The following discloses particular examples of methods used for increasing channel capacity.

[0006] United States Patent 5,345,599 shows a method for increasing capacity in wireless broadcast systems using distributed transmission/directional reception (DTDR). A method and apparatus is disclosed for increasing the capacity of wireless broadcast communications system from a central studio to a plurality of users in a service area. Given a source signal whose high information rate exceeds the practical information carrying capacity of the available broadcast channel bandwidth, the disclosure increases the effective capacity of the broadcast system to effectively communicate...
such a source signal. The high-rate signal is split into several low-rate signals such that each is accommodated within the allocated bandwidth. These low-rate signals are transmitted from spatially separated transmitters, all radiating into the service area in the same frequency channel. Each receiver uses a plurality of antennas to receive these multiple cochannel signals that arrive from different directions-of-arrival. The receiver exploits the directions-of-arrival differences of these cochannel signals to separate them into the individually transmitted signals. The separated signals are then demodulated to extract the information signals that are then combined to obtain the original high-rate source signal.

[0007] United States Patent 7,248,843 shows an antenna selection system and method. The system includes a transmitter that transmits a data signal having a time period without data transmission. The system also includes a receiver including a first antenna, a second antenna, a switch that activates one of the first antenna and the second antenna, and a processor that estimates a first signal-to-noise ratio for the first antenna and a second signal-to-noise ratio for the second antenna during the time period without data transmission. The processor controls the switch to select one of the first antennas and the second antenna based on a comparison between the first signal-to-noise ratio and the second signal-to-noise ratio.

[0008] United States Patent 7,327,983 shows a method for RF-based antenna selection in MIMO systems. A method is disclosed for processing signals of a multiple-input, multiple-output communications system in the RF domain. The system includes multiple transmit antennas and multiple receive antennas connected by a wireless channel. A matrix is generated based on long-term characteristics of the wireless channel. The matrix is multiplied by input RF signals to obtain output RF signals. The matrix is generated in a transmitter, a receiver, or both.

SUMMARY OF THE INVENTION

[0009] It is an object of the invention in its preferred form to provide a method and apparatus for antenna and transmission mode switching.
In accordance with a first aspect of the present invention, there is provided a method for antenna and transmission mode switching of a wireless communication channel, the method comprising the steps of: (a) calculating a switching criterion; (b) selecting a transmission mode on the basis of said switching criterion; and (c) selecting a respective antenna system in response to said selected transmission mode.

Preferably, the transmission mode is selected from the set comprising: a beamforming mode and a spatial multiplexing mode. Preferably, the antenna system is selected from the set comprising: an omnidirectional antenna and a sectorized antenna. Preferably, selecting a sectorized antenna system comprises the further step of selecting an antenna sector of said sectorized antenna system that best utilises a line-of-sight (LOS) transmission path for said communication channel. Preferably, the switching criterion is indicative of substantially equal calculated channel capacity for at least two selectable said transmission modes.

In accordance with another aspect of the present invention, there is provided, a device for antenna and transmission mode switching of a wireless communication channel, the device comprising: a transmission mode switch for selecting a transmission mode on the basis of said switching criterion; an antenna switch selecting a respective antenna system for said selected transmission mode; a processor element coupled to said transmission mode switch and said antenna switch; said processor adapted to perform the steps of: (a) calculating a switching criterion; (b) selecting a transmission mode on the basis of said switching criterion; and (c) selecting a respective antenna system in response to said selected transmission mode.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 shows an example system for transmitting an RF channel according to the present invention;
FIG. 2 shows an example flowchart for a method of antenna and transmission mode switching; and

FIG. 3 shows an example simulated performance results for 3x3 MIMO channel.

PREFERRED EMBODIMENT OF THE INVENTION

[0014] It will be appreciated that embodiments of the present invention can be utilised in wireless communication systems, including WLAN, WiFi, WiMax, 3G cellular, and ad-hoc wireless networks. It has been identified that, where multi-antennas are used, there can be advantages in methods that switch an antenna pattern associated with a transmission channel. By way of example only, this method can be used in aircraft wireless communications, where the long thin nature of the body lends itself to antenna switching.

[0015] Antenna switching is suitable for broadband wireless communications, and enables adaptive wireless communication having reconfigurable antennas.

[0016] An embodiment comprises an adaptive transmission method for multi antenna communication channels. This method includes two possible transmission schemes: spatial multiplexing and beamforming. Each Radio Frequency (RF) chain in a transmitter and/or receiver is connected to a switch that selects between two different antennas, which are specific to that RF chain. One antenna is an omnidirectional antenna and the other is a sectorized antenna. For each RF chain, and based on channel conditions, one of the two transmission schemes (or modes) is selected along with a corresponding antenna type. When a spatial multiplexing scheme is selected, an omnidirectional antenna is used for each RF chain to enable rich scattering multipaths. When a beamforming scheme is selected, a sectorized antenna is used for each RF chain, and a sector that is directed for a line-of-sight (LOS) transmission can be further selected. The overall selection can be based on a criterion of maximizing channel capacity.
In an embodiment, a method enables: a concept of switching between omnidirectional and sectorized antennas for multi antenna wireless communications; and a combination of switching both the transmission scheme and the antenna type to enhance the channel capacity; and use of antenna type switching to minimize interference.

The method can improve channel capacity over existing multi antenna communication schemes for changing channel conditions.

Existing transmission schemes which provide switching between spatial multiplexing and beamforming transmission modes, have been applied to increasing system capacity by adapting to the variation of fading channels. In these schemes, only omnidirectional antennas are used. It will be appreciated that, in highly correlated channels beamforming using narrow-beamwidth sectorized antennas is advantageous. Sectorized antennas can increase received signal strength of the line-of-sight (LOS) component. Sectorized antennas can also increase channel correlation, thereby increasing the maximal channel eigenvalue, which is favourable for a beamforming scheme.

Typical mode switching schemes use omnidirectional antennas at the transmitter side to create rich scattering multipath channels, and thereby increase the capacity of spatial multiplexing. It will be appreciated that omnidirectional antennas are not optimal for use in beamforming mode transmission scheme.

To overcome the disadvantages of only employing omnidirectional antennas in transmission scheme switching, and to further enhance the system capacity, the preferred embodiment utilizes a method that includes antenna type selection between omnidirectional and sectorized antennas. The antenna type selection can be based on a selected transmission scheme. This method can improve performance in application environments where the structure of the environment significantly shapes transmission channel characteristics and interference characteristics. It will be appreciated that, by way of example, application environments where a structure of
the environment significantly shapes transmission channel characteristics and interference characteristics can include long narrow corridors, buses, or within floors of multi-story buildings.

[0022] A method is disclosed that overcomes the disadvantage of using omnidirectional antennas in scheme switching and enhances system capacity. This method can adds a new dimension of adaptability by enabling adaptive selection between omnidirectional and sectorized antennas, and adding sectorized antennas at a transmitter. Mode switching combined with antenna type selection can improve channel capacity relative to existing mode switch schemes. In an embodiment, a 4 dB capacity improvement can be achieved in practical transmission environments, when compared with an existing transmission schemes.

[0023] A reconfigurable antenna system can enable spatial multiplexing, transition diversity and beamforming. Adaptive antenna selection and configuration can be adapted for a selected transmission mode.

[0024] FIG. 1 shows an example system 100 for transmitting an RF channel. In this system a processor element 110 is used to initiate the selection of a transmission mode and an antenna system. The transmission mode is selected from one of two possible transmission schemes using a mode switch 120 for each RF chain. In this example, the selectable transmission modes are a spatial multiplexing 122 or beamforming 124 transmission mode. Each RF chain in a transmitter is further connected to a respective antenna switch 130 that selects between one of two antenna systems specific to that RF chain. In this example, the antenna system is selected from either an omnidirectional antenna 140 or a sectorized antenna 150.

[0025] A sectorized antenna system is an antenna with multiple elements that can be separately activated. Each of these antenna elements is a directional antenna. For example, sectorized antennas can be designed to cover the whole horizontal plane; for example, using three antennas with 120° beamwidth, or six directional elements with
60° beamwidth. Sectorized antenna system can also be designed to have overlapping sectors, and/or to cover only certain segments of a transmission sphere.

[0026] One of the two transmission schemes, along with the corresponding antenna type for each RF chain, can be selected on the basis of identified channel conditions. It will be appreciated that antenna type and transmission mode switching can be achieved, at least in part, by a software implementation. The antenna system can be selected in response to the selected transmission mode.

[0027] A multi antenna transmission system is disclosed that combines antenna type and transmission mode switching. It will be appreciated that a receiver can comprise the same structure, allowing for a reversal in direction of any signal propagation.

[0028] In an embodiment, when transmission mode is switched to a spatial multiplexing scheme, each RF chain switches its respective antenna system to an omnidirectional antenna, for enabling a transmission having rich scattering multipaths. Alternatively, when transmission mode is switched to a beamforming scheme, each RF chain switches its respective antenna system to a sectorized antenna and further sub-selects the sector that best utilises a line-of-sight (LOS) transmission path. This can provide extra pattern gain in terms of signal strength and, consequently, additional channel capacity. The sub-selection of the sectorized antenna can be based on a RSSI (receive signal strength indicator). At the transmitter, the angle of departure for the LOS path can be used in support of a selection. An overall selection can be made on the basis of a criterion to maximize channel capacity.

[0029] Benefits of using a sectorized antenna in a beamforming transmission scheme includes: the use of directional antenna may increase the receive signal strength of the LOS component; and the use of directional antenna increases the LOS power and decrease NLOS power, thereby increases channel correlation, and hence increases the maximum channel eigenvalue.
FIG. 2 shows an example flowchart for a method of antenna and transmission mode switching. The method comprises:

(a) calculating a switching criterion 210;
(b) selecting a transmission mode on the basis of said switching criterion 220;
(c) selecting a respective antenna system at each RF chain for said selected transmission mode 230.

An example switching criterion for a spatial multiplexing system without channel state information can be calculated on the basis that transmission power is preferably equally distributed across all transmit antennas.

Spatial multiplexing channel capacity, denoted by $C_{SM}$, is expressed mathematically as:

$$C_{SM} = \log_2(\det(I_{N_t} + \frac{P}{N_t\sigma^2}HH^H)),$$

where $P$ is the total transmission power and $\sigma^2$ is the noise power on each receive antenna.

By applying singular value decomposition to a respective channel matrix, the channel capacity can be expressed mathematically as follows, where $\lambda_i$ is the $i$th channel eigenvalue.

$$C_{SM} = \sum_{i=1}^{m}\log_2(1 + \frac{P}{N_t\sigma^2}\lambda_i)$$

It will be appreciated that MIMO channel capacity is related to the characteristic of channel eigenvalues, which is determined by the spatial correlation of the multipath channel.
[0036] However, a beamforming transmission mode transmits a single data stream in the direction of the eigenvector corresponding to the largest eigenvalue of the MIMO channel denoted by $\lambda_{\text{MAX}}$. Therefore, beamforming channel capacity is can be expressed mathematically as follows.

$$C_{BF} = \log_2 \left(1 + \frac{P}{\sigma^2} \lambda_{\text{MAX}} \right)$$  \hspace{1cm} (3)

[0037] From equations (2) and (3) above, a switching point (or criterion) - identifying substantially equal channel capacity using either spatial multiplexing or beamforming - for a 2x2 MIMO link can be expresses as follows where $\lambda_1 \geq \lambda_2$.

$$\frac{P_c}{\sigma^2} = 2 \left( \frac{1}{\lambda_2} - \frac{1}{\lambda_1} \right)$$  \hspace{1cm} (4)

[0038] Defining $P_{SNR}^c = P_c \cdot \sigma^2$, the switching point occurs and spatial multiplexing is utilized when the SNR level is higher than $P_{SNR}^c$, otherwise beamforming is utilized. For 3x3 MIMO link, a switching point can be expressed mathematically as follows.

$$\frac{P_c}{\sigma^2} = \frac{3}{2} \sqrt{\frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2} + \frac{1}{\lambda_3^2} + \frac{10}{\lambda_1 \lambda_2 \lambda_3} - \frac{2}{\lambda_1 \lambda_2} - \frac{2}{\lambda_1 \lambda_3} - \frac{3}{2} \left( \frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3} \right)}$$  \hspace{1cm} (5)

[0039] For both equations (4) and (5), it will be appreciated that a switching condition $(P_{SNR}^c)$ increases with increasing correlation.

[0040] FIG. 3 shows simulated performance results 300 for 3x3 MIMO channel. The above method can be simulated for a 3x3 MIMO channel system, and the results show an improvement in channel capacity over an existing transmission schemes. These performance results are associated with a simulation of a 3x3 MIMO system in a LOS
channel (K=4), where direction antennas have a gain of 6 dB. It will be appreciated that, the proposed system achieves about a 4 dB gain.

[0041] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Interpretation

[0042] The invention may be embodied using devices conforming to other network standards and for other applications, including, for example other WLAN standards and other wireless standards. Applications that can be accommodated include IEEE 802.11 wireless LANs and links, and wireless Ethernet.

[0043] In the context of this document, the term "wireless" and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a non-solid medium. The term does not imply that the associated devices do not contain any wires, although in some embodiments they might not. In the context of this document, the term "wired" and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a solid medium. The term does not imply that the associated devices are coupled by electrically conductive wires.

[0044] Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing", "computing", "calculating", "determining" or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities into other data similarly represented as physical quantities.
In a similar manner, the term "processor" may refer to any device or portion of a device that processes electronic data, e.g., from registers and/or memory to transform that electronic data into other electronic data that, e.g., may be stored in registers and/or memory. A "computer" or a "computing device" or a "computing machine" or a "computing platform" may include one or more processors.

The methodologies described herein are, in one embodiment, performable by one or more processors that accept computer-readable (also called machine-readable) code containing a set of instructions that when executed by one or more of the processors carry out at least one of the methods described herein. Any processor capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken are included. Thus, one example is a typical processing system that includes one or more processors. The processing system further may include a memory subsystem including main RAM and/or a static RAM, and/or ROM.

Furthermore, a computer-readable carrier medium may form, or be included in a computer program product.

In alternative embodiments, the one or more processors operate as a standalone device or may be connected, e.g., networked to other processor(s), in a networked deployment, the one or more processors may operate in the capacity of a server or a client machine in server-client network environment, or as a peer machine in a peer-to-peer or distributed network environment. The one or more processors may form a web appliance, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine.

Note that while some diagram(s) only show(s) a single processor and a single memory that carries the computer-readable code, those in the art will understand that many of the components described above are included, but not explicitly shown or described in order not to obscure the inventive aspect. For example, while only a single machine is illustrated, the term "machine" shall also be taken to include any
collection of machines that individually or jointly execute a set (or multiple sets) of
instructions to perform any one or more of the methodologies discussed herein.

[0050] Thus, one embodiment of each of the methods described herein is in the form of a
computer-readable carrier medium carrying a set of instructions, e.g., a computer
program that are for execution on one or more processors. Thus, as will be
appreciated by those skilled in the art, embodiments of the present invention may be
embodied as a method, an apparatus such as a special purpose apparatus, an apparatus
such as a data processing system, or a computer-readable carrier medium. The
computer-readable carrier medium carries computer readable code including a set of
instructions that when executed on one or more processors cause a processor or
processors to implement a method. Accordingly, aspects of the present invention may
take the form of a method, an entirely hardware embodiment, an entirely software
embodiment or an embodiment combining software and hardware aspects.
Furthermore, the present invention may take the form of carrier medium (e.g., a
computer program product on a computer-readable storage medium) carrying
computer-readable program code embodied in the medium.

[0051] The software may further be transmitted or received over a network via a network
interface device. While the carrier medium is shown in an example embodiment to be
a single medium, the term "carrier medium" should be taken to include a single
medium or multiple media (e.g., a centralized or distributed database, and/or
associated caches and servers) that store the one or more sets of instructions. The
term "carrier medium" shall also be taken to include any medium that is capable of
storing, encoding or carrying a set of instructions for execution by one or more of the
processors and that cause the one or more processors to perform any one or more of
the methodologies of the present invention. A carrier medium may take many forms,
including but not limited to, non-volatile media, volatile media, and transmission
media.
[0052] It will be understood that the steps of methods discussed are performed in one embodiment by an appropriate processor (or processors) of a processing (i.e., computer) system executing instructions (computer-readable code) stored in storage. It will also be understood that the invention is not limited to any particular implementation or programming technique and that the invention may be implemented using any appropriate techniques for implementing the functionality described herein. The invention is not limited to any particular programming language or operating system.

[0053] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0054] Similarly it should be appreciated that in the above description of example embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the Detailed Description are hereby expressly incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of this invention.
Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

Furthermore, some of the embodiments are described herein as a method or combination of elements of a method that can be implemented by a processor of a computer system or by other means of carrying out the function. Thus, a processor with the necessary instructions for carrying out such a method or element of a method forms a means for carrying out the method or element of a method. Furthermore, an element described herein of an apparatus embodiment is an example of a means for carrying out the function performed by the element for the purpose of carrying out the invention.

In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

As used herein, unless otherwise specified the use of the ordinal adjectives "first", "second", "third", etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

In the claims below and the description herein, any one of the terms comprises, comprising, comprised of or which comprises is an open term that means including at least the elements/features that follow, but not excluding others. Thus, the term comprising, when used in the claims, should not be interpreted as being limitative to the means or elements or steps listed thereafter. For example, the scope of the
expression a device comprising A and B should not be limited to devices consisting only of elements A and B. Any one of the terms including or which includes or that includes as used herein is also an open term that also means including at least the elements/features that follow the term, but not excluding others. Thus, including is synonymous with and means comprising.

[0060] Similarly, it is to be noticed that the term coupled, when used in the claims, should not be interpreted as being limitative to direct connections only. The terms "coupled" and "connected", along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Thus, the scope of the expression a device A coupled to a device B should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means. "Coupled" may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

[0061] Thus, while there has been described what are believed to be the preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention. For example, any formulas given above are merely representative of procedures that may be used. Functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for antenna and transmission mode switching of a wireless communication channel, said method comprising the steps of:
   (a) calculating a switching criterion;
   (b) selecting a transmission mode on the basis of said switching criterion; and
   (c) selecting a respective antenna system in response to said selected transmission mode.

2. A method according to claim 1, wherein said transmission mode is selected from the set comprising: a beamforming mode and a spatial multiplexing mode.

3. A method according to any one of the preceding claims, wherein said antenna system is selected from the set comprising: an omnidirectional antenna and a sectorized antenna.

4. A method according to claim 3, wherein when selecting sectorized antenna system comprises the further step of selecting an antenna sector of said sectorized antenna system that best utilises a line-of-sight (LOS) transmission path for said communication channel.

5. A method according to any one of the preceding claims, wherein said switching criterion is indicative of substantially equal calculated channel capacity for at least two selectable said transmission modes.

6. A method according to any one of the preceding claims, wherein for a 2x2 MIMO transmission channel, said switching criterion is calculated using:

\[
\frac{P_c}{\sigma^2} = 2 \left( \frac{1}{\lambda_2} - \frac{1}{\lambda_1} \right),
\]
where $P$ is the total transmission power, $\sigma^2$ is the noise power on each receive antenna, $X_i$ is the $i$th channel eigenvalue of a respective channel matrix.

7. A method according to any one of the preceding claims, wherein for a 3x3 MIMO transmission channel, said switching criterion is calculated using:

$$\frac{P_c}{\sigma^2} = \frac{3}{2} \sqrt{\frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2} + \frac{10}{\lambda_1 \lambda_2} - \frac{2}{\lambda_1 \lambda_3} - \frac{2}{\lambda_2 \lambda_3} - \frac{3}{2} \left( \frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3} \right)},$$

where $P$ is the total transmission power, $\sigma^2$ is the noise power on each receive antenna, $X_i$ is the $i$th channel eigenvalue of a respective channel matrix.

8. A device for antenna and transmission mode switching of a wireless communication channel, said device comprising:

- a transmission mode switch for selecting a transmission mode on the basis of said switching criterion;
- an antenna switch selecting a respective antenna system for said selected transmission mode;
- a processor element coupled to said transmission mode switch and said antenna switch; said processor adapted to perform the steps of:
  - (a) calculating a switching criterion;
  - (b) selecting a transmission mode on the basis of said switching criterion; and
  - (c) selecting a respective antenna system in response to said selected transmission mode.

9. A device according to claim 8, wherein said transmission mode is selected from the set comprising: a beamforming mode and a spatial multiplexing mode.

10. A device according to claims 8 or claim 9, wherein said antenna system is selected from the set comprising: an omnidirectional antenna and a sectorized antenna.
11. A device according to any one of claims 8 to 10, wherein said switching criterion is indicative of substantially equal calculated channel capacity for at least two selectable said transmission modes.

12. A computer-readable carrier medium carrying a set of instructions that when executed by one or more processor elements cause the one or more processor elements to carry out a method of according to any one of claims 1 to 7.

13. A computer-readable carrier medium carrying a set of instructions that when executed by one or more processor elements cause the one or more processor elements to carry out a method substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.

14. A method for antenna and transmission mode switching of a wireless communication channel, substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.

15. A device for antenna and transmission mode switching of a wireless communication channel, said device comprising a processor element coupled to a transmission mode switch and an antenna switch, said processor element being adapted for performing a method according to any one of the preceding claims.

16. A device for antenna and transmission mode switching of a wireless communication channel, substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.
2/3

200

Calculate a switching criterion

210

Select a transmission mode on the basis of the switching criterion

220

Select a respective antenna system for the selected transmission mode.

230

FIG. 2
## INTERNATIONAL SEARCH REPORT

### A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

*H04B 7/04 (2006.01) HOIQ 3/24 (2006.01)*

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)

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 practicable, search terms used)

WPI, EPODOC - keywords (antenna, transmission mode, switching criteria, MIMO) and similar terms

GOOGLE - keywords (antenna, transmission, adaptive, mode, switching, criteria, MIMO) and similar terms

IEEE - keywords (antenna, transmission mode, switching criterion, MIMO) and similar terms

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 2006/0083 195 A1 (FORENZA et al.) 20 April 2006 Abstract; paragraphs 0014-0016, 0024-0025, 0041, 0045-0047</td>
<td>1-4, 8-10, 12, 15</td>
</tr>
</tbody>
</table>


| X         | Abstract; sections I, m, V-VII | 1-4, 6-10, 12 |

[ ] 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
  
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  '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

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Date of the actual completion of the international search: 31 March 2010

Date of mailing of the international search report: - 6 APR 2010

Name and mailing address of the ISA/AU

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Form PCT/ISA/2 10 (second sheet) (July 2009)
INTERNATIONAL SEARCH REPORT

Box No. II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  

   □ Claims Nos.:  
   because they relate to subject matter not required to be searched by this Authority, namely:

2.  

   □ Claims Nos.: 13-14, 16  
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
   Claims 13-14, 16 do not comply with Rule 6.2(a) because they rely on references to the drawings and/or examples.

3.  

   □ Claims Nos.:  
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  

   □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2.  

   □ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3.  

   □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4.  

   □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

□ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

□ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

□ No protest accompanied the payment of additional search fees.

Form PCT/ISA/2 10 (continuation of first sheet (2)) (July 2008)
## INTERNATIONAL SEARCH REPORT

**International application No.**
PCT7AU2010/000101

**C (Continuation).**

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<td>WO 2005/048486 A1 (BROADCOM CORPORATION) 26 May 2005 Abstract; paragraphs 09, 11-12, 39, 43-46, 48, 57; figures 1a, 2b, 2b, 3</td>
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Form PCT/ISA/2 10 (continuation of second sheet) (July 2009)
This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX