Title: ANTENNA ARRANGEMENT AND METHODS OF TRANSMISSION AND RECEPTION AT A BASE STATION

Abstract: The area of coverage of a cellular wireless communications network is divided into sectors, each sector having a respective predetermined set of frequencies selected for use in the sector. Radio frequency signals are transmitted from an antenna arrangement (8a, 8b, 8c) of a base station of the cellular wireless communications network in a first beam (10a) to a first sector and the same radio frequency signals are transmitted simultaneously transmitted in a second beam (12a) to a second sector, the first (10a) and second (12a) beams having substantially opposite directions in azimuth, and the first sector having the same predetermined set of frequencies (f1) as the second sector. The radio frequency signals comprise at least a first signal for communication with a first user terminal in the first sector and at least a second signal for communication with a second user terminal in the second sector, the first signal being different from the second signal.

Figure 5
Antenna Arrangement and Methods of Transmission and Reception at a Base
Station

Technical Field

The present invention relates generally to radio antennas, and more specifically, but not exclusively, to an antenna arrangement and to methods of transmission and reception at a base station of a cellular wireless communications network.

Background

Modern wireless communications networks place great demands on the antennas used to transmit and receive signals. In a cellular wireless communications network, the area of coverage of the network is divided into cells, each cell having a respective predetermined set of frequencies selected for use in the sector, selected from frequencies within an operating frequency band for the network. Each respective predetermined set of frequencies is re-used by other cells in the network according to a pre-determined re-use pattern. Typically, in a cellular wireless communications network, the cells may be areas of coverage that are formed as angular sectors around each base station site, each sector being served by a respective antenna beam. Typically, adjacent sectors of the same base station operate at a different predetermined set of frequencies, to avoid interference between sectors.

The capacity of a cellular system may be increased by providing a greater degree of frequency re-use. This may be achieved, for example, by increasing the number of sectors into which the area of coverage of a base station is divided. In order to achieve this, the base station antennas are typically required to produce narrow beams to serve the intended sector, but it is also typically required that radiation into other sectors operating in the same set of frequencies is kept below strict limits. In some re-use patterns, the same set of frequencies is re-used in diametrically opposite sectors of a base station coverage area. This would typically be the case, for example, if three sets of
frequencies are re-used in a hex-sectored arrangement, that is to say the area of coverage of a base station is divided into six sixty-degree sectors. This re-use arrangement may be used, for example, in a high capacity fixed wireless access network. In cases where the same set of frequencies is re-used in diametrically opposite sectors of a base station coverage area, it is typically required that radiation in the opposite direction to the intended beam is limited, so that an antenna design providing a high front/back isolation is typically required. Such antennas may be expensive, and/or bulky, providing undesirable wind resistance on an antenna tower.

On initial deployment of a network, the customer base may not be fully developed, so the demands for capacity may be relatively low. Therefore, on initial deployment, a high degree of frequency re-use may not be required. However, it is typically difficult to change a frequency re-use pattern in a network once it is deployed, so conventionally a high degree of frequency re-use may be provided on initial deployment, typically requiring antennas having a high degree of front/back isolation to be installed.

It is an object of the invention to mitigate the problems of the prior art.

Summary

In accordance with a first aspect of the present invention, there is provided a method of transmitting signals from an antenna arrangement of a base station of a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector having a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the method comprising:

transmitting radio frequency signals in a first beam to a first sector and simultaneously transmitting the same radio frequency signals in a second beam to a second sector, the first and second beams having substantially opposite
directions in azimuth, and the first sector having the same predetermined set of frequencies as the second sector,

wherein the radio frequency signals comprise at least a first signal for communication with a first user terminal in the first sector and at least a second signal for communication with a second user terminal in the second sector, the first signal being different from the second signal.

This has an advantage that the same allocation of frequencies to sectors may be used for an initial deployment of a cellular network as will be used subsequently, but in the initial deployment, pairs of sectors operating with the same sets of frequencies at the same base station can be operated together as single cells. This may reduce the expense and complexity of an initial deployment, since antennas with high front/back isolation may not be required, and a reduced number of radio transceivers may be deployed. Subsequently, the network may be upgraded so that paired sectors are operated as separate cells, each transmitting different signals from the other, by deploying further radio transceivers and antennas with higher front/back isolation. This upgrade may be implemented without changing the pattern of frequency allocation to sectors. As a result, the upgrade may be carried out incrementally, with the upgrade of each base station being possible without changing the frequency allocation at other base stations.

In an embodiment of the invention, the first signal comprises first payload data for the first user terminal and the second signal comprises second payload data for the second user terminal.

This has an advantage that both the first and second terminal may be served by a single transceiver and antenna part.

In an embodiment of the invention, the method comprises transmitting further radio frequency signals in a third beam to a third sector and simultaneously transmitting the same further radio frequency signals in a fourth beam to a fourth sector, the third and fourth beams having substantially opposite directions in azimuth, and the third sector having the same predetermined set of frequencies as the fourth sector.
This has an advantage that a further pair of sectors may be operated as a single cell, similarly to the first and second sectors.

In accordance with a second aspect of the invention, there is provided a method of receiving signals from an antenna arrangement of a base station of a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector having a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the method comprising:

receiving radio frequency signals in a first beam from a first sector and in a second beam from a second sector, the first and second beams having substantially opposite directions in azimuth, and the first sector having the same predetermined set of frequencies as the second sector; and

combining the radio frequency signals received in the first beam and the radio frequency signals received in the second beam for connection to a receiver,

wherein the combined radio frequency signals for connection to the receiver comprise at least a first signal for communication with a first user terminal in the first sector and at least a second signal for communication with a second user terminal in the second sector, the first signal being different from the second signal.

This has similar advantages to the corresponding method of transmitting, in that the same allocation of frequencies to sectors may be used for an initial deployment of a cellular network as will be used subsequently, but in the initial deployment, pairs of sectors operating with the same sets of frequencies at the same base station can be operated together as single cells, which may reduce the expense and complexity of an initial deployment. In a time division duplex system, the same frequencies re-use plan is typically used for transmitted and received signals. In a frequency division duplex system, different frequencies
are used for transmitted signals than are used for received signals, but the
frequency re-use pattern is typically arranged to maintain the same pairing
between transmitted and received signals between sectors.

In an embodiment of the invention, the first signal comprises payload
data for the first user terminal and the second signal comprises payload data for
the second user terminal.

This has an advantage that both the first and second terminal may be
served by a single transceiver and antenna part.

In an embodiment of the invention, the method comprises receiving
further radio frequency signals in a third beam from a third sector and in a fourth
beam from a fourth sector, the third and fourth beams having substantially
opposite directions in azimuth, and the third sector having the same
predetermined set of frequencies as the fourth sector; and

combining the further radio frequency signals received in the third beam
and the radio frequency signals received in the fourth beam for connection to a
receiver.

This has an advantage that a further pair of sectors may be operated as a
single cell, similarly to the first and second sectors.

In accordance with a third aspect of the invention, there is provided an
antenna arrangement for a base station of a cellular wireless communications
network, the area of coverage of the network being divided into a plurality of
sectors, each sector being designated to operate within a respective
predetermined set of frequencies selected for use in the sector, the set of
frequencies being selected from frequencies within an operating frequency band
for the network, and each respective predetermined set of frequencies being re-
used by others of the plurality of sectors according to a pre-determined re-use
pattern, the antenna arrangement comprising:

a first antenna part having a first connection port for connection to a first
transceiver and a first radiating part for producing a first beam for a first sector
and a second radiating part for producing a second beam for a second sector, the
first and second beams having substantially opposite directions in azimuth,
wherein the first and second radiating parts are connected by a radio frequency splitter to the first connection port for connection to the first transceiver.

This has an advantage that the antenna arrangement may be used for an initial deployment of a cellular network, that uses the same allocation of frequencies to sectors may be used for subsequent upgrades. In the initial deployment, pairs of sectors operating with the same sets of frequencies at the same base station can be operated together as single cells. This may reduce the expense and complexity of an initial deployment, since antennas with high front/back isolation may not be required, and a reduced number of radio transceivers may be deployed. The first antenna part may be produced economically from two radiating parts, such as patch antenna elements, each forming a beam, connected to a single transceiver. Subsequently, the network may be upgraded so that paired sectors are operated as separate cells, each transmitting different signals from the other, by deploying further radio transceivers and antennas with higher front/back isolation. This upgrade may be implemented without changing the pattern of frequency allocation to sectors. As a result, the upgrade may be carried out incrementally, with the upgrade of each base station being possible without changing the frequency allocation at other base stations.

In an embodiment of the invention, the first radiating part comprises at least a first patch antenna element disposed in a substantially parallel relationship to a ground plane, and the second radiating part comprises at least a second patch antenna element disposed in a substantially parallel relationship to the ground plane, on the opposite side of the ground plane to the side on which the first patch antenna is disposed.

This has an advantage that the first radiating part may be produced cheaply using existing multi-layered printed circuit board technology.

In an embodiment of the invention, the first radiating part comprises a first array of antenna elements and the second radiating part comprises a second array of antenna elements.
This has an advantage that the first and second beam patterns may be defined by the first and second array arrangements, to give a potentially narrower beam than may be achieved by a single patch antenna. Control of the beam shape may be achieved in both elevation and azimuth by use of an appropriate array configuration.

In an embodiment of the invention, the antenna arrangement comprises a second antenna part having a second connection port for connection to a second transceiver and at least one radiating part for radiating signals received at the connection port, the at least one radiating part being configured to radiate a third beam and a fourth beam, the third and fourth beams having substantially opposite directions in azimuth,

wherein the second antenna part is disposed to provide coverage for a third sector using the third beam, and to provide coverage for a fourth sector using the fourth beam, the third and fourth sectors both being designated to operate within a second pre-determined set of frequencies, different from the first predetermined set of frequencies.

This has an advantage that a further pair of sectors may be operated as a single cell, similarly to the first and second sectors.

In an embodiment of the invention, the first and/or second antenna part is configured for attachment to a mounting fixture such that the respective antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the beams of the respective antenna part.

This has an advantage that the respective antenna part may be conveniently mounted on a mounting fixture such as a pole or tower without the mounting fixture blocking either of the beams produced by the antenna part. Furthermore, several antenna parts may be mounted to the mounting fixture, disposed radially around the fixture, without blocking each other's beams.

In an embodiment of the invention, the antenna arrangement further comprises a transceiver coupled to the first antenna part to transceive a signal simultaneously in both the first and second beams.
In accordance with a fourth aspect of the invention, there is provided a base station for a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector being designated to operate within a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the base station comprising an antenna arrangement comprising:

- a first antenna part having a first connection port for connection to a first transceiver and at least one radiating part for radiating signals received at the connection port, the at least one radiating part being configured to radiate a first beam and a second beam, the first and second beams having substantially opposite directions in azimuth,

wherein the first antenna part is disposed to provide coverage for a first sector using the first beam, and to provide coverage for a second sector using the second beam, the first and second sectors both being designated to operate within a first pre-determined set of frequencies.

Further features and advantages of the invention will be apparent from the following description of preferred embodiments of the invention, which are given by way of example only.

**Brief Description of the Drawings**

Figure 1 is a schematic diagram showing conventional hex sector reuse pattern for a fixed wireless access network;

Figure 2 is a schematic diagram showing a conventional base station antenna with high front/back isolation;

Figure 3 is a schematic diagram showing conventional base station antenna arrangement for hex sectors;
Figure 4 is a schematic diagram showing an antenna part for use at a base station in an embodiment of the invention;

Figure 5 is a schematic diagram showing a base station antenna arrangement in an embodiment of the invention;

Figure 6 is a schematic diagram showing an antenna mounting arrangement according to an embodiment of the invention for a hex sector reuse pattern;

Figure 7 is a schematic diagram showing a hex sector reuse pattern for a fixed wireless access network in an embodiment of the invention;

Figure 8 is a schematic diagram showing a conventional quad sector reuse pattern;

Figure 9 is a schematic diagram showing a quad sector reuse pattern in an embodiment of the invention;

Figure 10 is a schematic diagram showing an antenna mounting arrangement according to an embodiment of the invention for a quad sector reuse pattern;

Figure 11 is a schematic diagram showing an antenna part in an embodiment of the invention implemented by two radiating parts and a splitter;

Figure 12 is a schematic diagram showing a cross section of an antenna part comprising radiating patches on either side of a ground plane in an embodiment of the invention;

Figure 13 is a schematic diagram showing a plan view of an antenna part comprising radiating patches in an embodiment of the invention; and

Figure 14 is a schematic diagram showing a plan view of an antenna part comprising an array of radiating patches in an embodiment of the invention.

**Detailed Description**

By way of example, embodiments of the invention will now be described in the context of a broadband fixed wireless access radio communications system operating in accordance with an IEEE 802.11a, b, g, n or ac standard. However, it will be understood that this is by way of example only and that
other embodiments may involve other wireless systems, and may apply to mobile cellular radio systems.

Figure 1 shows an example of a conventional frequency re-use pattern for use in a fixed wireless access system. It can be seen that in this example, a base station 14a is surrounded by six sectors, each of approximately 60 degrees, and that three frequency sets, f₁, f₂, and f₃, are re-used between the sectors and between the base stations. It can be seen from Figure 1 that in this arrangement, each frequency set is re-used at a base station between diametrically opposite sectors. It can be seen that a first beam 6a serves a first sector at f₁ with a first set of signals carrying payload data d₁, and that a second beam 6b serves a second sector also at f₁ with a second set of signals carrying different payload data d₂. Payload data may be, for example, voice or internet traffic, or other forms of data carried by the wireless communications network to or from a user terminal.

Figure 2 shows an antenna arrangement that may be used in the cellular arrangement of Figure 1, for example at a base station of a cellular wireless network. An antenna 4 having a high front/back isolation performance is typically used to form a beam 6 to serve a sector, while minimising interference to a diametrically opposite sector operating at the same frequency but carrying different signals with different payload data. Typically radiation in the opposite direction to the beam should be at a level 30 dB or more below the transmitted radiation in the main beam 6. The antenna is connected to a transceiver 2, which may comprise a transmitter and/or a receiver, for serving the sector.

Figure 3 shows how an arrangement of 6 antennas as shown in Figure 2 may be disposed at a base station within the cellular arrangement of Figure 1. Each antenna 4a - 4f is connected to a respective transceiver at the base station and forms a respective beam 6a - 6f.

Figure 4 shows an antenna part 8 for use in an antenna arrangement at a base station in an embodiment of the invention. As can be seen from Figure 4, the antenna part is connected to a single transceiver 2 and is arranged to form a first beam 10 and a second beam 12 in substantially opposite directions in
azimuth. The antenna part may be used for transmitting and/or receiving. It will be understood that antennas are typically reciprocal devices that may be use for either transmission or reception; reference to a beam may refer to a transmission beam and/or a reception beam.

Figure 5 illustrates that several antenna parts as shown in Figure 4 may be disposed in different orientations in an antenna arrangement at a base station to provide coverage to sectors of a base station in an embodiment of the invention. In the example of Figure 5, six sectors of a base station may be covered by the use of three of the antenna parts of Figure 4, disposed at increments of 120 degrees to one another. In this way, diametrically opposite sectors are arranged to operate at the same sets of frequencies, but re-use of frequencies is not provided between the opposite sectors. Instead, the same signals are transmitted to both sectors.

Figure 6 illustrates an antenna mounting arrangement according to an embodiment of the invention for a hex sector re-use pattern. As may be seen, the antenna parts 8a, 8b, 8c are configured for attachment to a mounting fixture 7 such that the antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the beams. For example, each antenna part may have two radiating faces on two sides, with two non-radiating ends connected to the sides, and be provided with a mounting bracket on one of the ends. The mounting bracket may be used to connect the antenna part to the mounting fixture, such that the antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the beams. Three antennas parts may be disposed as shown, disposed around the mounting fixture in the azimuth plane at substantially 120 degree intervals for a hex sectored pattern.

Figure 7 illustrates an example of a cellular network arrangement in an embodiment of the invention. It can be seen that, similar to the conventional approach illustrated by Figure 1, a base station 20a is surrounded by six sectors, each of approximately 60 degrees. Three frequency sets, \( f_1, f_2 \) and \( f_3 \) are provided, and these frequency sets are re-used between the base stations to carry
different signals with different payload data. However, in the example of Figure 7, each frequency set is used at a base station between diametrically opposite sectors, but each diametrically opposite sector is served with the same signals, with the same payload data. It can be seen that a first beam 10 serves a first sector at f with a first set of signals carrying payload data if, and that a second beam 12 serves a second sector also at f with the same first set of signals carrying the same payload data if.

So, as illustrated by Figure 7, signals are transmitted and/or received from an antenna arrangement of a base station 20a, 20b, 20c of a cellular wireless communications network. The area of coverage of the network is divided into sectors as shown in the example of Figure 7, each sector having a respective predetermined set of frequencies selected for use in the sector. The set of frequencies is selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies f₁, f₂, f₃ is re-used by others of the plurality of sectors according to a pre-determined re-use pattern, as shown by the allocation of f₁, f₂, f₃ to sectors in Figure 7. Other re-use patterns are possible.

Radio frequency signals are transmitted and/or received in a first beam 10 to a first sector and transmitted and/or received in a second beam 12 to a second sector, the first and second beams having substantially opposite directions in azimuth, and the first sector having the same predetermined set of frequencies as the second sector, in the example of Figure 7, f₁. As the same signals are transmitted simultaneously in both the first and second beams, and the first and second beams are connected to the same transceiver, the radio frequency signals typically comprise at least one signal for communication with a first user terminal in the first sector and at least one signal for communication with a second user terminal in the second sector. The radio frequency signals may comprise both payload data for the first user terminal and payload data for the second user terminal, so that both the first and second terminal may be served by a single transceiver and antenna part.
The arrangement of Figure 7 allows an initial deployment of a cellular network to use the same allocation of frequencies to sectors as may be used subsequently for an upgraded network of higher capacity as shown in the example of Figure 1. In the initial deployment, pairs of sectors operating with the same sets of frequencies at the same base station can be operated together as single cells, which typically reduces the expense and complexity of an initial deployment, since antennas with high front/back isolation may not be required, and a reduced number of radio transceivers may be deployed. Subsequently, the network may be upgraded so that paired sectors are operated as separate cells, each transmitting different signals from the other, by deploying further radio transceivers and antennas with higher front/back isolation. This upgrade may be implemented without changing the pattern of frequency allocation to sectors. As a result, the upgrade may be carried out incrementally, with the upgrade of each base station being possible without changing the frequency allocation at other base stations.

As illustrated by Figures 5, 6 and 7, several antenna parts, each forming two beams in opposite directions, may be deployed together at a base station. In the example of Figure 7, the antenna parts may be disposed at substantially 120 degree increments to give coverage for three respective sets of frequencies $f_1$, $f_2$ and $f_3$. So, as illustrated by Figure 5, in addition to the radio frequency signals transmitted and/or received at $f$ in the first beam 10a and the second beam 12a, further radio frequency signals, at $f_2$ in this example, are transmitted and/or received in a third beam 10b to/from a third sector and the further radio frequency signals transmitted and/or received in a fourth beam 12b to/from a fourth sector, the third and fourth beams having substantially opposite directions in azimuth, and the third sector having the same predetermined set of frequencies as the fourth sector, in this example $f_2$. In this way, the radio signals are transmitted in the first beam to the first sector, and the same radio frequency signals are simultaneously transmitted in the second beam to the second sector, and the further radio signals are transmitted in the third beam to the third sector, and the same further radio frequency signals are simultaneously
transmitted in the fourth beam to the fourth sector. On reception, the radio frequency signals comprise signals received in the first and second beams, typically received simultaneously. The radio frequency signals received in the first beam and the radio frequency signals received in the second beam are combined together for connection to a receiver. The receiver may be, for example, part of a transceiver for reception of signals from the first and second sectors. Similarly, the further radio frequency signals comprise signals received in the third and fourth beams, typically received simultaneously. The further radio frequency signals received in the fourth beam are combined together for connection to a receiver, which may be, for example, part of a transceiver for reception of signals from the third and fourth sectors. Typically the receiver for reception of the further radio frequency signals received from the third and fourth beams is tuned to receive different frequencies than is the receiver for reception of the radio frequency signals received from the first and second beams.

So, a further pair of sectors may be operated as a single cell, similarly to the first and second sectors, and yet further pairs may be added, in the example of Figure 5, antenna part 8c may produce beams 10c and 12c.

Figure 8 illustrates an alternative cellular frequency re-use pattern to that used in Figure 1, that may be referred to as quad pattern. In the example of Figure 8, four frequency sets $f_1$, $f_2$, $f_3$ and $f_4$ are re-used in a cellular wireless communications network, and the area of coverage of a base station 20a is divided into four sectors, each sector being covered by an antenna beam of approximately 90 degrees beamwidth. It can be seen that in the example of Figure 8, two frequency sets are used at each base station, and the same frequency set is used for beams opposite in azimuth. So, for example first beam 6a and second beam 6b both operate at first frequency set $f_1$, but in the conventional approach illustrated by Figure 8, different signal are transmitted in the first 6a and second 6b beams, so a high front/back isolation antenna is needed to form each beam, to reduce interference to the opposite beam.
Figure 9 illustrates how a quad pattern may be implemented in an embodiment of the invention. It may be seen that opposite beams 10, 12 are, similarly to the hex pattern illustrated in Figure 7, used to transmit and/or receive the same signals as each other, carrying the same payload data di.

Figure 10 illustrates an antenna mounting arrangement according to an embodiment of the invention for a quad sector re-use pattern. Similarly to the arrangement illustrated by Figure 6, the antenna parts 8a, 8b are configured for attachment to a mounting fixture 7 such that the antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the beams. Two antennas parts may be disposed as shown, disposed around the mounting fixture in the azimuth plane at substantially 90 degrees to one another for a quad sectored pattern.

Figure 11 illustrates an antenna part 8 that may be used as part of an antenna arrangement at a base station of a cellular wireless communications network. The antenna part has a first connection port 24 for connection to a first transceiver 2 and at least one radiating part 16, 18 for radiating signals received at the connection port 24. The radiating part or parts are configured to radiate a first beam 10 and a second beam 12, the first and second beams having substantially opposite directions in azimuth. As illustrated for example in Figure 7, the first antenna part is disposed to provide coverage for a first sector using the first beam, and to provide coverage for a second sector using the second beam, the first and second sectors both being designated to operate within a first pre-determined set of frequencies. That is to say, the antenna part is aligned, for example by attachment to an antenna tower, to provide coverage to the respective sectors according to the pre-determined frequency re-use pattern. The antenna arrangement may be used for an initial deployment of a cellular network, that uses the same allocation of frequencies to sectors may be used for subsequent upgrades. Subsequently, the network may be upgraded so that paired sectors are operated as separate cells, each transmitting different signals from the other, by deploying further radio transceivers and antennas with higher front/back isolation. This upgrade may be implemented without
changing the pattern of frequency allocation to sectors. As a result, the upgrade may be carried out incrementally, with the upgrade of each base station being possible without changing the frequency allocation at other base stations.

As shown in Figure 11, the first antenna part 8 may have a first radiating part 16 for producing the first beam 10 and a second radiating part 18 for producing the second beam 12. The first and second radiating parts may be connected by a radio frequency splitter 21 to the first connection port 24 for connection to the first transceiver 2, so that two radiating parts, such as patch antenna elements, may be used, each forming a beam, connected to a single transceiver.

The beams, for example the first and second beams, may each, for example, have a beamwidth of less than or equal to 90 degrees, and may for example have a beamwidth less than or equal to 60 degrees.

As shown in Figure 12, the first radiating part 16 may comprise at least a first patch antenna element 28 disposed in a substantially parallel relationship to a ground plane 32, and the second radiating part 18 may comprise at least a second patch antenna element 30 also disposed in a substantially parallel relationship to the ground plane 32, on the opposite side of the ground plane to the side on which the first patch antenna is disposed. In this way, the first radiating part may be produced cheaply as a multi-layered printed circuit board 26. The board may comprise, for example, copper layers from which the patch antenna elements 28, 30 and the ground plane 32 are formed, supported by a dielectric substrate such as an epoxy resin/glass composite material to form the multilayered board. An example of such a board is shown in cross-section in Figure 12. In an alternative embodiment, the first and second patch antenna elements may be separated from the ground plane by spacers, for example non-conductive plastic spacers, so that the dielectric material between the antenna elements and the ground plane is air.

As shown in Figure 13, each patch antenna element 34 may be connected to a feed track 36 typically formed, as is conventional, at an appropriate characteristic impedance for connection to a splitter/combiner, such as a well-
known Wilkinson microstrip combiner, which may be connected to an input/output port of the antenna part for connection to a transceiver. Figure 13 shows a patch antenna element in plan view, corresponding one of the patch antenna elements 28, 30 shown in cross section in Figure 12.

As shown in Figure 14, the first radiating part may comprise a first array of antenna elements 38a - 38h, and the second radiating part may similarly comprises a second array of antenna elements. In this way, the first and second beam patterns may be defined by the first and second array arrangements, to give a potentially narrower beam than may be achieved by a single patch antenna. Control of the beam shape may be achieved in both elevation and azimuth by use of an appropriate array configuration. The antenna elements may be patch antenna elements as illustrated by Figures 12 and 13, connected to the splitter/combiner 21 by a conventional feed network, arranged to feed the antenna elements with appropriate relative phases and/or amplitudes to produce the respective beams.

The antenna arrangement may comprises a second antenna part, typically similar to the first antenna part, having a second connection port for connection to a second transceiver and at least one radiating part for radiating signals received at the connection port, the at least one radiating part being configured to radiate a third beam and a fourth beam, the third and fourth beams having substantially opposite directions in azimuth. The second antenna part may be disposed to provide coverage for a third sector using the third beam, and to provide coverage for a fourth sector using the fourth beam, the third and fourth sectors both being designated to operate within a second pre-determined set of frequencies, different to the first predetermined set of frequencies. This may be achieved by mounting the second antenna part so that the direction of the third beam is at an offset angle in azimuth from the angle of the first beam, the offset angle being appropriate to the frequency re-use sector pattern used at the base station. For example, in a hex sectored pattern as illustrated in Figure 7, the offset angle may be substantially 120 degrees. In a quad sectored pattern as illustrated in Figure 9, the offset angle may be substantially 90 degrees. In
addition, if the antenna parts are mounted on a mast, they may be offset from the mast by, for example, a bracket, to prevent the mast from blocking one of the transmitted and/or received beams.

The above embodiments are to be understood as illustrative examples of the invention. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.
Claims

1. A method of transmitting signals from an antenna arrangement of a base station of a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector having a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the method comprising:

- transmitting radio frequency signals in a first beam to a first sector and simultaneously transmitting the same radio frequency signals in a second beam to a second sector, the first and second beams having substantially opposite directions in azimuth, and the first sector having the same predetermined set of frequencies as the second sector,

wherein the radio frequency signals comprise at least a first signal for communication with a first user terminal in the first sector and at least a second signal for communication with a second user terminal in the second sector, the first signal being different from the second signal.

2. A method according to claim 1, wherein the first signal comprises first payload data for the first user terminal and the second signal comprises second payload data for the second user terminal.

3. A method according to claim 1 or claim 2, comprising transmitting further radio frequency signals in a third beam to a third sector and simultaneously transmitting the same further radio frequency signals in a fourth beam to a fourth sector, the third and fourth beams having substantially opposite directions in azimuth, and the third sector having the same predetermined set of frequencies as the fourth sector.
4. A method of receiving signals from an antenna arrangement of a base station of a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector having a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the method comprising:

- receiving radio frequency signals in a first beam from a first sector and in a second beam from a second sector, the first and second beams having substantially opposite directions in azimuth, and the first sector having the same predetermined set of frequencies as the second sector; and
- combining the radio frequency signals received in the first beam and the radio frequency signals received in the second beam for connection to a receiver,

wherein the combined radio frequency signals for connection to the receiver comprise at least a first signal for communication with a first user terminal in the first sector and at least a second signal for communication with a second user terminal in the second sector, the first signal being different from the second signal.

5. A method according to claim 4, wherein the first signal comprises payload data for the first user terminal and the second signal comprises payload data for the second user terminal.

6. A method according to claim 4 or claim 5, comprising:

- receiving further radio frequency signals in a third beam from a third sector and in a fourth beam from a fourth sector, the third and fourth beams having substantially opposite directions in azimuth, and the third sector having the same predetermined set of frequencies as the fourth sector; and
combining the further radio frequency signals received in the third beam and the radio frequency signals received in the fourth beam for connection to a receiver.

7. An antenna arrangement for a base station of a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors, each sector being designated to operate within a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the antenna arrangement comprising:

a first antenna part having a first connection port for connection to a first transceiver and a first radiating part for producing a first beam for a first sector and a second radiating part for producing a second beam for a second sector, the first and second beams having substantially opposite directions in azimuth, wherein the first and second radiating parts are connected by a radio frequency splitter to the first connection port for connection to the first transceiver.

8. An antenna arrangement according to claim 7, wherein the first radiating part comprises at least a first patch antenna element disposed in a substantially parallel relationship to a ground plane, and the second radiating part comprises at least a second patch antenna element disposed in a substantially parallel relationship to the ground plane, on the opposite side of the ground plane to the side on which the first patch antenna is disposed.

9. An antenna arrangement according to claim 7 or claim 8, wherein the first radiating part comprises a first array of antenna elements and the second radiating part comprises a second array of antenna elements.
10. An antenna arrangement according to any of claims 7 to 9, comprising:

- a second antenna part having a second connection port for connection to a second transceiver and at least one radiating part for radiating signals received at the connection port, the at least one radiating part being configured to radiate a third beam and a fourth beam, the third and fourth beams having substantially opposite directions in azimuth,

wherein the second antenna part is disposed to provide coverage for a third sector using the third beam, and to provide coverage for a fourth sector using the fourth beam, the third and fourth sectors both being designated to operate within a second pre-determined set of frequencies, different from the first predetermined set of frequencies.

11. An antenna arrangement according to claim 10, wherein the second antenna part is configured for attachment to a mounting fixture such that the second antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the third and fourth beams.

12. An antenna arrangement according to any of claims 7 to 11, wherein the first antenna part is configured for attachment to a mounting fixture such that the first antenna part is radially offset from the mounting fixture in a direction in an azimuth plane substantially normal to the direction of the first and second beams.

13. An antenna arrangement according to any one of claims 7 to 12, further comprising a transceiver coupled to the first antenna part to transceive a signal simultaneously in both the first and second beams.

14. A base station for a cellular wireless communications network, the area of coverage of the network being divided into a plurality of sectors,
each sector being designated to operate within a respective predetermined set of frequencies selected for use in the sector, the set of frequencies being selected from frequencies within an operating frequency band for the network, and each respective predetermined set of frequencies being re-used by others of the plurality of sectors according to a pre-determined re-use pattern, the base station comprising an antenna arrangement comprising:

a first antenna part having a first connection port for connection to a first transceiver and at least one radiating part for radiating signals received at the connection port, the at least one radiating part being configured to radiate a first beam and a second beam, the first and second beams having substantially opposite directions in azimuth,

wherein the first antenna part is disposed to provide coverage for a first sector using the first beam, and to provide coverage for a second sector using the second beam, the first and second sectors both being designated to operate within a first pre-determined set of frequencies.
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**Figure 8**

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**PRIOR ART**