APPARATUS FOR DISTRIBUTING/COMBINING A MULTI-BEAM IN A MOBILE COMMUNICATION SYSTEM

The present invention relates to an apparatus of dividing a multi-beam from a base station for several n sectors and combining vice versa in a mobile communication system. The present apparatus includes a multi-beam forming module consisting of n multi-beam forming means forming a received multi-beam from m antennas in a mobile communication system to m beams, which have different direction each other; a 180° coupling module combining the (mXn) beams from the multi-beam forming module to (mXn)/2 beams; a switching module choosing each beam path of the beams from the 180° coupling module; a 180° phase shifting module shifting signal phase to strengthen a part of the beams outputted from the switching module; and a mixing module adapting characteristics of amplitude and phase of the beams while mixing them. According to the present invention, data traffic of a base station can be distributed equally among its n sectors.

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DESCRIPTION

APPARATUS FOR DISTRIBUTING/COMBINING A MULTI-BEAM IN A MOBILE COMMUNICATION SYSTEM

1. Technical Field

The present invention relates to a multi-beam dividing/combining apparatus of a mobile communication system capable of changing service coverage of each sector based on traffic load on each sector.

2. Background Art

In a mobile communication system, a base station (BTS) is classified into two types, 'omni' and 'sector'. However, most base stations are 'sector' type. In a sector-typed BTS, its service area is divided into three or six sectors. A sector-typed BTS in the CDMA system has three sectors in general.

The sector-typed BTS uses antennas with fixed beamwidth for each sector, thus, the geographic area of coverage of a sector is fixed. However, because traffic is usually unbalanced among sectors of a BTS, the frequency resource is allotted enough for a sector processing the heaviest traffic. As a result, the efficiency of frequency resource is low in a sector of light traffic and, in a sector of heavy traffic, the efficiency of wireless channels may be decreased and the coverage may be shrunked. Therefore, there arise problems such as low service efficiency and high frequency resource management/maintenance cost in a BTS having traffic-unbalanced sectors.

Furthermore, if the distribution of traffic load is changed among three sectors in a BTS of which sectors have
respective fixed coverage, such situation is manually dealt with, namely, an operator turns antenna mounted on a steel tower properly to adapt to the change of traffic load distribution. However, such manual works are very dangerous and tedious, and the antenna adjusting time is too long as well. In conclusion, manual maintenance is inefficient.

3. Disclosure of Invention

It is an object of the present invention to provide a multi-beam dividing/combining apparatus of a mobile communication system which allocates a beam of a sector to another sector to adjust each coverage of all sectors based on traffic load distribution in order to ensure traffic balance among sectors and effective use of frequency resources of a BTS.

A multi-beam dividing/combining apparatus of a mobile communication system in accordance with the present invention is characterized in that, where a base station has n sectors with m beams for each sector, it comprises a multi-beam forming module forming (nxm) beams of which radiation angles are different each other; a 180° coupling module combining the (nxm) beams from the multi-beam forming module into (nxm)/2 beams each of which is divided between two sectors; a switch module consisting of (nxm) switch elements each of which selects one of the divided (nxm) beams or a terminating load; a 180° phase shifting module shifting phase of the divided (nxm) beams selectively; and a combining module combining m/2 beams for each sector.

Another multi-beam dividing/combining apparatus of a mobile communication system in accordance with the present invention is characterized in that, where a base station has n sectors with m beams for each sector, it comprises a multi-beam forming module forming (nxm) beams of which radiation angles are different each other; a switch module
consisting of switch elements selectively connecting \((nxm)/2\) beams among the \((nxm)\) output beams of the multi-beam forming module to two sectors, respectively; a coupling module consisting a plurality of sector couplers and a plurality of common couplers, the sector couplers combining the \((nxm)/2\) beams not via the switch module and the \((nxm)/2\) beams via the switch module, each of the common couplers being capable of combining two beams from said two switch elements and of dividing the combined beam between two sectors; and a combining module combining all outputs from the coupling module for each sector.

Another multi-beam dividing/combining apparatus of a mobile communication system in accordance with the present invention is characterized in that, where a base station has \(n\) sectors with \(m\) beams for each sector, it comprises a coupling module coupling the \((nxm)\) beams to produce traffic estimating criterion signals of each sector; a switch matrix module consisting of \((nxm)\) switch elements each of which is capable of connecting each input to two sectors; a terminated switch matrix module consisting of \(2x(nxm)\) terminated switch elements each of which selects an output of the switch element or a terminating load; a combining module combining all outputs from the terminated switch matrix module for each sector; and a controlling unit controlling individually the switching operations of the switch elements and the terminated switch elements based on the produced traffic estimating criterion signals.

The multi-beam dividing/combining apparatus of a mobile communication system makes it possible to use frequency resources effectively and improves stability and convenience of maintenance through traffic balance among all sectors. In this multi-beam dividing/combining apparatus, the number of switches requisite for switching beams is included as least
as it can, therefore, stable operation of beam change can be achieved.

4. Brief Description of Drawings

The accompanying drawings, which are included to provide a further understanding of the present invention, illustrate the preferred embodiments of the invention, and together with the description, serve to explain the principles of the present invention, and wherein:

Fig. 1 is illustrative beam patterns radiated by the first embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention;

Fig. 2 is a block diagram of the first embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention;

Fig. 3 is illustrative sector-fixed and sector-changeable beams radiated by the second embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention;

Fig. 4 is a block diagram of the second embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention;

Fig. 5 is a block diagram of the third embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention; and

Fig. 6 is a detailed block diagram of the multi-beam dividing/combining apparatus of Fig. 5.

5. Modes for Carrying out the Invention

In order that the invention may be fully understood, a preferred embodiment thereof will now be described with reference to the accompanying drawings.

The first embodiment of the present invention is explained, first. In the first embodiment, four beams for each sector (total twelve beams for three sectors) are combined
into two beams so that total six beams can be allocated to one of three sectors adaptively based on traffic distribution.

Namely, six beams are formed for entire service coverage of a BTS as shown in Fig. 1 and the direction and width of a sector is adjusted through beam re-allocation.

Fig. 2 is a block diagram of the first embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention. The apparatus of Fig. 2 comprises a multi-beam forming module 102, a 180° coupling module 104, a switch module 106, a 180° phase shifting module 108, and a combining module 110.

The multi-beam forming module 102 forms twelve beams of which radiation angles are different each other and it includes three multi-beam formers for three sectors as shown in Fig. 2. The four RF beams outputted from each multi-beam former are applied to two 180° couplers in the 180° coupling module 104.

The 180° coupling module 104 consisting of six 180° couplers combines the twelve RF beams to six ones, namely, each 180° coupler in the 180° coupling module 104 combines two RF beams into one. And, every 180° coupler has two output signal paths, one connected toward a signal port of its original sector and the other connected toward a signal port of another sector.

The switch module 106 selects outputs of the 180° couplers if signals are outputted from them. Owing to the 180° coupling module 104 and the switch module 106, each beam can be allocated to one of three sectors adaptively. The 180° phase shifting module 108 shifts phases of the output signals of the switches receiving signals from other sectors in order that signal from other sector might be mixed constructively in the next combining module 110.
The combining module 110 matches beams each other in their amplitude and phase characteristics on every signal paths from the multi-beam forming module 110. The combining module 110 can be made of 4-way combiners.

In accordance with operation of the first embodiment of a multi-beam dividing/combining apparatus, six beams can be allocated to a sector other than their original sector, respectively for the purpose of adapting to change of traffic load distribution among three sectors, whereby the efficiency of wireless channels can be maximized.

Now, the second embodiment of the present invention is explained. In the second embodiment, four beams for each of three sectors (total twelve beams for three sectors) are used and the four beams are composed of two fixed and two sector-changeable beams (referred 'adaptive beam' hereinafter). The two adaptive beams of each sector can be re-allocated to other sector adaptively based on traffic distribution.

Namely, twelve beams are formed for entire service coverage of a BTS wherein six beams A2, A3, B2, B3, C2, and C3 are fixed to their original sectors and the other six beams A1, A4, B1, B4, C1, and C4 are changeable between sectors, as shown in Fig. 3. Thus, the direction and width of a sector is adjusted through adaptive beam re-allocation.

Fig. 4 is a block diagram of the second embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention. The apparatus of Fig. 4 comprises a multi-beam forming module 402, a switch module 404, a 180° coupling module 406, and a combining module 408.

The multi-beam forming module 402 forms twelve beams of which radiation angles are different each other and it includes three multi-beam formers for three sectors as shown in Fig. 4. Each multi-beam former forms four beams received
from an array sector antenna in order that the four beams might have mutually different coverage cells which constitute whole coverage of a corresponding sector.

The switch module 404 of the second embodiment has six switches arranged for the six beams A4, B1, B4, C1, C4, and A1 which are configured as 'sector-changeable' at initial stage. Each switch in the switch module 404 receives an adaptive beam from the multi-beam forming module 402 and connects it toward an original or both original and other sector.

Each switch in the switch module 404 includes two outputs and one terminating load. An output has fixed connection to the input and the other output is selectively connected to the input or the terminating load according to an external control signal or an internal control signal of the switch module 404. Namely, each switch forms single beam path toward an output port of its original sector only or two paths toward both its sector and other one. In other words, each switch functions as a 2-way divider when it is ON and as a single beam path when it is OFF.

The switches connected to beam ports A1, A4, B1, B4, C1, and C4 operate in pairs. In other words, two switches, A4 and B1, B4 and C1, or C4 and A1 are coupled in switching operation. For example, the two switches for A4 and B1 port are in OFF at the same time or one of the two becomes ON when the other becomes OFF. Namely, each couple of the switches make no path to other sectors or make only single path to other sector under an external ON/OFF control signal or an internal ON/OFF control signal of the switch module 404.

Each coupler of the 180° coupling module 406 includes two inputs and two or one (the other is terminated) output and it shifts the phase of a diagonal input by 180° and then combines it with a direct input.
The combining module 408 matches beams each other in their amplitude and phase characteristics on every signal paths from the multi-beam forming module 402. The combining module 408 can be made of 4-way combiners.

The operation of the second embodiment is illustratively explained in more detail.

When the couple of switches A4 and B1 are all OFF, no beam path to other sectors is established so that the two adaptive beams A4 and B1 are fixed to their original sectors, respectively. If all couples of the switches are OFF, then the sector-typed BTS has twelve fixed beams as conventional.

When the switch A4 of the two is ON and the other B1 is OFF, the beam A4 is divided by the switch A4 functioning as a 2-way combiner and is applied to two 180° couplers, namely the 180° coupler of sector 1 and the common 180° coupler placed between sectors 1 and 2, at the same time. The beam A4 applied to the 180° coupler of sector 1 is shifted by 180° whereas no shift in phase takes place in the beam A4 applied to the common 180° coupler. Therefore, the divided beams A4 are mixed destructively in the combiner of sector 1 so that the beam A4 disappears in sector 1.

In the meantime, the divided beam A4 applied to the common 180° coupler is shifted by 180° at the output connected to sector 2 and then is entered to the combiner of sector 2. The 180°-shifted beam A4 is combined with the beam B1 with 180° shift and other beams of sector 2 in the combiner of sector 2. Therefore, the beam A4 is re-allocated from sector 1 to sector 2, namely, the coverage of sector 2 is widened.

Similar to the above-explained operation, when the switch A4 is OFF and the other B1 of the two is ON, the beams A4 and B1 are combined in the combiner of sector 1 so that the beam B1 is re-allocated to sector 1. The detailed explanation for this case is omitted since it is apparent to
those skilled in the art.

In accordance with operation of the second embodiment of a multi-beam dividing/combining apparatus, six beams of twelve beams can be allocated to a sector other than their original sector respectively for the purpose of adapting to change of traffic load distribution among three sectors, whereby the efficiency of wireless channels can be maximized.

Now, the third embodiment of the present invention is explained. In the third embodiment, four beams for each of three sectors (total twelve beams for three sectors) are used and all the twelve beams are sector-changeable so that they can be re-allocated to other sector adaptively based on traffic distribution.

Fig. 5 is a block diagram of the third embodiment of a multi-beam dividing/combining apparatus in accordance with the present invention. The apparatus 500 of Fig. 5 comprises a directional coupling module 502, a switch matrix module 504, a terminated switch matrix module 506, a beam combining module 508, and a controlling unit 600.

The directional coupling module 502 couples RF beams from array antennas (not figured) to extract partial signals of the RF beams. The coupled signals are used as determination criterion for adaptive beam re-allocation of the multi-beam dividing/combining apparatus 500 and it may be also used for estimating traffic in a reverse link.

The switch matrix module 504 connects or diverts outputs from the directional coupling module 502 toward proper sectors and matches signal characteristics between the directional coupling module 502 and the terminated switch matrix module 506.

The terminated switch matrix module 506 connects signals from the switch matrix module 504 to its outputs or terminates if there are not signals. It also matches signal
characteristics between the switch matrix module 504 and the beam dividing/combining module 508.

The beam dividing/combining module 508 arranged for three sectors divides/combines the multi-beam and matches characteristics of signals transmitted/received to/from a BTS system (not figured).

The controlling unit 600 controls switching operations of both the switch matrix module 504 and the terminated switch matrix module 506 and keeps monitoring their switched states.

Fig. 6 is a detailed block diagram of the multi-beam dividing/combining apparatus 500 of Fig. 5. As shown in Fig. 6, the directional coupling module 502 couples twelve beams from twelve input terminals connected to three array antennas to produce the aforementioned criterion signals and connects the twelve beams to the switch matrix module 504.

The switch matrix module 504 includes twelve switches which match signal characteristics between the directional coupling module 502 and the terminated switch matrix module 506 under control of the controlling unit 600. Also, each switch of the switch matrix module 504 selects beam path to either of two sectors under control of the controlling unit 600. For beam path selection, each switch of the switch matrix module 504 has one input, connected to the directional coupling module 502, and two outputs connected to two terminated switches belonging to different sectors.

Therefore, switching operation of each switch determines one sector of the two.

The terminated switch matrix module 506 includes twenty four terminated switches which match signal characteristics between the switch matrix module 504 and the beam dividing/combining module 508 under control of the controlling unit 600. Each terminated switch of the terminated switch matrix module 506 has two inputs, one
connected to the switch matrix module 504 and the other connected to a terminating load. Thus, the output of each terminated switch is connected to a corresponding switch in the switch matrix module 504, if it outputs signal, or is connected to the terminating load under control of the controlling unit 600. The switching to the terminating load is for not only impedance matching among the switch matrix module 504, the terminated switch matrix module 506, and the beam dividing/combining module 508 but also prevention of unwanted noise inflow into system.

As known by the explanation of all elements of the apparatus 500 shown in Figs. 5 and 6, traffic load of each sector is estimated based on the extracted signals from the coupled paths by the directional coupling module 502 and it is determined how to divide/combine the multi-beam based on the estimated traffic load of each sector. Then, the controlling unit 600 sets all physical signal paths through the switch matrix module 504 and the terminated switch module 506 by controlling their respective switching according to the determined multi-beam dividing/combining scheme. The physical signal paths set by the controlling unit 600 carry out physical changes of sectors.

It will be apparent to those skilled in the art that various modifications and variations can be made in the explained embodiments, e.g., in the number of beams, the number of sectors, and structure of twelve switches without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.
CLAIMS

1. A multi-beam dividing/combining apparatus of a mobile communication system in which a base station has \( n \) sectors with \( m \) beams for each sector, comprising:
   a multi-beam forming module forming \((nxm)\) beams of which radiation angles are different each other;
   a \(180^\circ\) coupling module combining the \((nxm)\) beams from the multi-beam forming module into \( (nxm)/2 \) beams each of which is divided between two sectors;
   a switch module consisting of \((nxm)\) switch elements each of which selects one of the divided \((nxm)\) beams or a terminating load;
   a \(180^\circ\) phase shifting module shifting phase of the divided \((nxm)\) beams selectively; and
   a combining module combining \(m/2\) beams for each sector.
2. The apparatus of claim 1, wherein the \(180^\circ\) coupling module divides each combined beam between an original sector and other sector.
3. The apparatus of claim 1, wherein the switch module makes each of the combined \( (nxm)/2 \) beams be selected to single sector.
4. The apparatus of claim 1 or 2, wherein the \(180^\circ\) phase shifting module shifts the half of the divided \((nxm)\) beams to combine them constructively, the half being from other sectors.
5. A multi-beam dividing/combining apparatus of a mobile communication system in which a base station has \( n \) sectors with \( m \) beams for each sector, comprising:
   a multi-beam forming module forming \((nxm)\) beams of which radiation angles are different each other;
a switch module consisting of switch elements
selectively connecting \((nxm)/2\) beams among the \((nxm)\) output
beams of the multi-beam forming module to two sectors, respectively;

5 a coupling module consisting a plurality of sector
couplers and a plurality of common couplers, the sector
couplers combining the \((nxm)/2\) beams not via the switch module
and the \((nxm)/2\) beams via the switch module, each of the common
couplers being capable of combining two beams from said two
switch elements and of dividing the combined beam between two
sectors; and

a combining module combining all outputs from the
coupling module for each sector.

6. The apparatus of claim 5, wherein the coupling module
conveys constantly the \((nxm)/2\) beams directly from the
multi-beam forming module to respective original sectors and
is capable of conveying the other \((nxm)/2\) beams to both of
an original and other sector at the same time.

7. The apparatus of claim 5, wherein the coupling module
conveys one of the divided beams by each switch element to
an original sector with no phase shift and the other of the
divided beams to the original sector with \(180^\circ\) phase shift,
and also conveys said one beam to other sector with \(180^\circ\) phase
shift.

8. The apparatus of claim 5 or 7, wherein the switch
element outputs an input beam to the sector coupler and the
common coupler at the same time when ON signal is applied and
connects the input beam to only the sector coupler when OFF
signal is applied.

9. The apparatus of claim 5, wherein the combining
module further matches beams each other in their amplitude
and phase characteristics on every signal paths from the
multi-beam forming module.
10. A multi-beam dividing/combining apparatus of a mobile communication system in which a base station has \( n \) sectors with \( m \) beams for each sector, comprising:

- a coupling module coupling the \( (n \times m) \) beams to produce \( 5 \) traffic estimating criterion signals of each sector;
- a switch matrix module consisting of \( (n \times m) \) switch elements each of which is capable of connecting each input to two sectors;
- a terminated switch matrix module consisting of \( 2 \times (n \times m) \) terminated switch elements each of which selects an output of the switch element or a terminating load;
- a combining module combining all outputs from the terminated switch matrix module for each sector; and
- a controlling unit controlling individually the switching operations of the switch elements and the terminated switch elements based on the produced traffic estimating criterion signals.

11. The apparatus of claim 10, wherein each switch element makes a beam path to an original sector or other sector according to the switching control of the controlling unit.

12. The apparatus of claim 10, wherein each terminated switch element makes a beam path between the switch element and the combining module or terminates an input of the combining module according to the switching control of the controlling unit.

13. The apparatus of claim 10, wherein the terminating load is connected for preventing unwanted noise inflow by cutting off the beam path between the switch matrix module and the combining module.

14. The apparatus of claim 10, wherein the combining module matches characteristics of signals transmitted/received to/from a base station system.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H04B 7/155

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

Patents Search System in KIPO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>Y</td>
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