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(54) MULTIBEAM ANTENNA FOR MOBILE TELEPHONE BASE STATION

(57) A multibeam antenna for a mobile telephone base station which comprises, basically: a two-dimensional matrix of radiating elements (2) with double polarization, in which the radiating elements (2) are grouped in one-dimensional or multi-dimensional arrays (3a, 3b, ..) and where both the different arrays (3a, 3b, ..) of radiating elements (2) and the distribution networks are completely independent of each other in radioelectric terms, and in which the vertical and horizontal beam widths in each array of radiating elements can be personalised and optimised independently of the other beams, in such a way that each distribution network or phase shifter (5) has moving parts which change the phase given to the radiating elements (2), allowing dynamic variation in the azimuth angle of each array (3a, 3b, ..) in a completely independent manner.

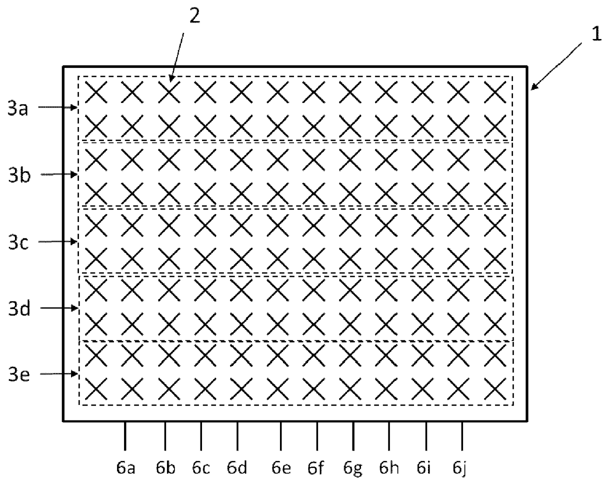

FIG. 4

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Description

OBJECT OF THE INVENTION

[0001] The following invention, as stated in the title of this descriptive report, refers to a multibeam antenna for a mobile telephone base station, in which a first object of this invention is for the beam forming networks to be flexible, allowing antennae with multiple beams to be formed, with variable pointing directions and optimised beam widths, without penalising the overall dimensions of the antenna.

[0002] Another object of the invention is for the beam bandwidth to be considerably greater than conventional ones, from 1710 to 2690MHz, which is in ever greater demand for cellular network antennae, in both the single beam and multiple beam variants.

FIELD OF APPLICATION

[0003] This application describes a multibeam antenna for a mobile telephone base station, which is in the field of mobile communication base station antennae, and more specifically in the field of cellular communication system multibeam antennae.

BACKGROUND OF THE INVENTION

[0004] The widely recognised term "multibeam antenna" refers to an antenna which can radiate in different directions.

[0005] The concept of multibeam antennae was introduced for the first time in the field of satellite communications where coverage for a geographical area is provided by generating multiple beams with great gain, so that frequencies can be re-used, thus achieving a saving in the power transmitted at the same time as increased transmission rates.

[0006] Terrestrial mobile communication networks also have to cover a wide geographical area, divided into cells and, in turn, into sectors. A traditional way of providing coverage for the cell is to deploy a telecommunications tower in the centre of the cell and install three antennae on it, where each antenna has a single radiation beam with an azimuth beam width at half power of 65 degrees and gives coverage to a third of the cell (figure 1).

[0007] A common practice for increasing the capacity of the cell in geographical areas with high population density is to divide the cell into more sectors by using antennae with smaller azimuth beam width, which increases the number of antennae used per cell according to the configuration shown in figure 2.

[0008] A particular case of mass use can be found in places holding special events, such as sports stadiums and concerts, where great capacity is required to manage large volumes of voice and data traffic in a limited space for a brief period of time. Multibeam antennae were introduced in the field of mobile telephone base stations to provide a solution to this problem, using a greater sectorisation of the cell by positioning a single antenna which has various radiation beams at different azimuth angles.

[0009] There are currently multibeam antennae which offer this characteristic, but lack other exclusive features of this invention.

[0010] All the current solutions are based on beamforming networks (BFNs) based on Butler matrices:

- The patent CN202474227U (Dual-polarized three-beam antenna for mobile communication base station) presents a mode of implementation of an antenna with 6 entry ports and three dual-polarized beams (+45 degrees and -45 degrees), with fixed pointing directions of 0 degrees and ±40 degrees.
- The patent CN202474228U (Dual-polarized five-beam antenna for mobile communication base station) presents a mode of implementation of an antenna with 10 entry ports and five dual-polarized beams (+45 degrees and -45 degrees), with fixed pointing directions of 0 degrees, ±20 degrees and ±40 degrees.
- The patent CN202474223U (Dual-polarized eight-wave beam antenna for mobile communication base station) presents a mode of implementation of an antenna with 16 entry ports and eight dual-polarized beams (+45 degrees and -45 degrees), with fixed pointing directions of ±10 degrees, ±20 degrees, ±40 degrees and ±60 degrees.

[0011] In all of these prior inventions, because of the technology used for the beamforming network based on Butler matrices, the pointing directions of the radiation beams are fixed and the isolation between beams very limited (approximately 18dB). In many cases, these pointing direction and beam width restrictions do not satisfy the needs of the operators. Because of the characteristics inherent in the Butler matrices used for the beamforming networks, the smaller the number of beams, the more the nominal pointing directions separate and the larger the beam widths. This does not divide the cell correctly into sectors and the necessary capacity to cover large-scale events is not achieved. If the number of beams is increased, smaller sectors are achieved, but even so, this is not sufficient and the drawback is the need for a larger, heavier antenna. Of the aforementioned patents, the one most used is the five beam system because of its compromise between size and number of beams; however, it does not meet expectations for very large-scale events because blind areas without coverage remain between beams, and the beams are wider than desired.

[0012] In the field of mobile telephone antennae, there are a number of well-known mechanisms for remote control of the tilt of the main radiation beam, which are also called RET (Remote Electrical Tilt) systems such as, for example, the one described in patent application no. P201530770. This invention expands this concept for the remote control of the azimuth angle of the radiation beam of each of the beams of the multibeam antenna.

DESCRIPTION OF THE INVENTION

[0013] This report describes a multibeam antenna for a mobile telephone base station, comprising:

a. a two-dimensional matrix of radiating elements with dual polarization;

- the radiating elements are each arranged in groupings of one-dimensional or multi-dimensional arrays, in a horizontal or azimuthal direction;
- each grouping of arrays of the radiating elements form a radiation beam of the multibeam antenna;
- the number of beams is modular and easily scalable through modular incorporation of groupings of arrays of the radiating elements;

b. as many pairs of radio frequency signal entry ports as beams;

- the signal from each pair of radio frequency ports is distributed in power and phase in an array grouping of radiating elements by means of distribution networks, also called beamforming networks or phase shifters.

c. the different groupings of arrays of radiating elements and the distribution networks are totally independent of each other in radioelectric terms.
d. the vertical and horizontal beam widths of each beam of radiating elements can be personalised and optimised independently of the remaining beams.
e. each phase shifter has moving parts which vary the phase given to the radiating elements, allowing the azimuth angle of each grouping of arrays to be varied dynamically in a completely independent manner.

[0014] Thus, in a practical execution of the invention, the radiating elements of the matrix are five two-dimensional arrays in 2x12 composition, presenting an azimuthal beam width at half power of 7 degrees, and nominal beam pointing directions of 0, +7, +14, -7 and -14 degrees, in which each beam can be varied by +/-5 degrees compared to its nominal position, and independently of the rest.

[0015] The radio frequency signal present in each of the entry ports passes through a first power and phase distribution network which distributes the signal in a horizontal direction, where each of the outputs from this first distribution network passes through a second distribution network which distributes the power and phase in a vertical direction, where each of the outputs in this second distribution network attacks a radiating element.

[0016] In addition, according to this practical execution, each array grouping comprises two radiating elements in a vertical direction, where the second distribution network is a simple "T"-shaped network which shares out the power equally between the two radiating elements and provides the same phase to the two radiating elements, giving electrical tilt of the beam equal to 0 degrees.

[0017] Thus, each array grouping comprises two radiating elements in a vertical direction, where the second distribution network is a simple "T"-shaped network which shares out the power equally between the two radiating elements and provides a different phase to each of the radiating elements, giving fixed electrical tilt different from 0 degrees.

[0018] Each array grouping comprises three or more radiating elements in a vertical direction, where the second distribution network shares out the power and phase between the radiating elements generating an array factor in a vertical direction which defines the form and tilt of the global beam in a vertical direction.

[0019] Meanwhile, all the second distribution networks present at the output of a first distribution network must be equal to each other, so that the beam generated by the two-dimensional array grouping is not degraded.

[0020] To complement the description being made below, and to make it easier to better understand the characteristics of the invention, this descriptive report is accompanied by a set of drawings in which, for illustrative and not restrictive purposes, the following has been represented.

BRIEF DESCRIPTION OF THE DESIGNS

[0021]

Figure 1 shows a schematic diagram showing the traditional deployment of a mobile communications cell composed of three sectors, where each sector is covered by an antenna with a single beam with an azimuthal angle at half power of 65 degrees.
Figure 2 shows a schematic diagram showing the traditional deployment of a mobile communications cell composed of six sectors, where each sector is covered by an antenna with a single beam with an azimuthal angle at half power of 33 degrees.
Figure 3 shows a horizontal radiation diagram of the multibeam antenna, according to a first practical embodiment of this invention.
Figure 4 shows the diagram of the distribution of radiating elements according to the first practical embodiment of this invention.
Figure 5 shows a practical embodiment of the radiating element according to the aforementioned practical first embodiment formed of two orthogonal radiating dipoles.
Figure 6 shows a connection diagram for the entry signal to each radiating element passing through dis-

tribution networks which make up the beam.

Figure 7 shows a second practical embodiment of this invention, where the array groupings are not all equal to each other, for greater optimisation of the cell and traffic management.

Figure 8 shows a horizontal radiation diagram according to the second practical embodiment of the distribution of arrays as shown in figure 7.

Figure 9 shows a vertical radiation diagram of the first embodiment of the antenna, according to figures 3 and 4.

Figure 10 shows an image of the multibeam antenna.

Figure 11 shows a third embodiment of this invention, in which the arrays are not all equal to each other, for greater simplification of the antenna.

Figure 12 shows a diagram of the mechanism for adjusting the azimuth directions of each of the beams.

Figure 13 shows a mechanical mechanism used in the practical embodiment of this invention for movement of the moving parts in the distribution network which adjusts the azimuth.

DESCRIPTION OF A PREFERRED EMBODIMENT

[0022] In light of the figures mentioned above and in accordance with the numbering adopted, we can observe the description of a multibeam antenna for a mobile telephone base station, whose antenna has double polarization for mobile communication base stations. Each radiation beam has a different azimuth pointing direction which can be varied dynamically according to the cell optimization requirements. The sum of all the beams covers the desired geographical area by generating a highly sectorised cell, where each beam forms a sector, multiplying the cell capacity by a factor equal to the number of beams presented by the multibeam antenna.

[0023] Unlike the rigidity of the features of the beamforming networks based on Butler matrices, the beamforming networks in this invention are flexible, allowing antennae with multiple beams to be achieved, with variable pointing directions and optimised beam widths, without penalising the overall dimensions of the antenna.

[0024] Another fundamental advantage of the distribution networks on which this invention is based, compared to the distribution networks based on Butler matrices, is the beam width; the multibeam antennae which exist today and are widely used by the operators have a bandwidth of 1710-2170MHz, whereas this invention exhibits a considerably higher beam width of 1710 to 2690MHz, which is increasingly demanded by cellular network antennae, for both the single beam and multiple beam variants.

[0025] The practical materialisation of this invention shows a five beam antenna with the horizontal radiation diagram shown in figure 3, but the diagram is totally modular and the number of beams desired can be increased or decreased without this meaning a novelty with regard to the one shown in this description.

[0026] Figure 4 shows a diagram of a first practical embodiment of this invention, where the multibeam antenna 1 is formed of a matrix of radiating elements 2 grouped in arrays 3a 3b, 3c, 3d and 3e arranged in a horizontal direction.

[0027] Each array 3a 3b, 3c, 3d and 3e of elements forms a radiation beam and are independent of each other, which means that the number of beams can be varied simply by varying the number of arrays.

[0028] Each matrix of radiating elements grouped in an array can be one-dimensional or two-dimensional.

[0029] The one-dimensional arrays comprise a row of radiating elements, whereas the two-dimensional ones comprise two or more rows of radiating elements, like the arrays 3a, 3b, 3c, 3d, 3e shown in figure 4. The choice of the composition of the array is made according to the desired features for each lobe or radiation beam, as explained later on.

[0030] A multibeam antenna according to this invention may comprise simultaneously one-dimensional arrays and two-dimensional arrays. In the first practical embodiment of this invention, an antenna with five beams has been implemented, in which each beam is formed of a two-dimensional array in 2x12 composition, with 12 elements in a horizontal direction and 2 in a vertical direction.

[0031] According to the first practical execution, each radiating element in the array (figure 5) comprises, in turn, two radiating dipoles arranged in an orthogonal position, forming an angle of +45 and -45 to the horizontal, thus forming dual polarization of the radiation lobes.

[0032] As a second variant, each radiating element of the array can be formed of a radiating patch with two orthogonal power ports arranged at an angle of +45 and -45 degrees to the horizontal, thus forming dual polarization of the radiation lobes.

[0033] The radiating elements of the array used must have good radioelectric characteristics in all the design bandwidth (1710 - 2690MHz in the materialisation of this invention).

[0034] The multibeam antenna which is the object of this invention comprises two radiofrequency signal ports for each array 3a 3b, 3c, 3d and 3e horizontal, where one port attacks the radiating elements of polarization +45 and the other port attacks the radiating elements of polarization -45.

[0035] For a dual polarization five beam antenna, 10 signal ports are thus needed.

[0036] The number of radiating elements per array and the distribution of power and phase from the entry signal to each of the radiating elements does not have to be the same in each array, and depends just as much on the desired pointing direction as the desired beam width.

[0037] In the first practical embodiment developed in this invention, the distribution of powers and phases have been designed to point to nominal azimuth angles of 0 degrees, ±7 degrees and ±14 degrees, but is not restricted to this. The fact that the arrays are independent of each other means that the pointing directions of the beams are totally flexible and can be configured in the design phase, with any combination possible.

[0038] In order to be able to vary dynamically the azimuth pointing direction of each array, distribution networks have been arranged which distribute the power and phase of the entry signal between each radiating element and, thus, figure 6 shows in diagram form a first distribution network or phase shifter 5 for one of the two-dimensional arrays 3a, which is attacked by two signal ports 6a and 6b. The first distribution network or phase shifter 5 distributes the power and phase from port 6a between the radiating elements arranged for the +45 polarization, and distributes the power and phase from port 6b between the radiating elements arranged for the -45 polarization.

[0039] In a two-dimensional array like the one shown in figure 6, each of the outputs from the first distribution network or phase shifter 5 must attack more than one radiating element, which means that a second distribution network 7 is needed. The simplest composition for this second distribution network 7 is a "T" network which shares the power equally among all the elements with a same phase, achieving a vertical beam with no electrical tilt, or tilt of 0 degrees. Nevertheless, the distribution of power and phase can vary to form the vertical beam and offer electrical tilt.

[0040] In the first practical embodiment of this invention, the horizontal phase shifters 5 offer a phase distribution such that the pointing direction can vary +/-5 degrees compared to the nominal pointing direction, but is not restricted to this, and this relative phase shift can be increased or decreased. These phase shifters achieve practical pointing directions for the first beam of between +19 and +9 degrees , for the second beam of +12 to +2 degrees, for the third beam of +5 to -5 degrees, for the fourth beam of -2 to -12 degrees and for the fifth beam of -9 to -19 degrees.

[0041] Given that the necessary phase shift for the entry signal must be high to achieve a pointing in a range of +19 to -19 degrees, the distance between radiating elements in a single array is not implemented equidistantly to optimise the radiation diagram and reduce the lobes deriving from the array factor. With the same aim in mind, not all the arrays are implemented equally, but rather each one is optimised according to the azimuth range which must be presented.

[0042] The set of distribution networks used in this invention may appear more complex than the Butler matrices, but they offer much greater flexibility, achieving improvements and optimised radioelectric features in a large bandwidth.

[0043] The fact that the distribution network or phase shifter 5 is independent for each horizontal array 3a 3b, 3c, 3d and 3e gives the antenna very good features in terms of isolation between any of its ports, higher than 30dBs in any event.

[0044] As mentioned previously, this invention is not limited to the pointing directions, nor to the relative displacement of the beams with regard to the main direction, nor to a fixed distribution of radiating elements, but rather any of these three design criteria can be varied without this meaning an additional invention, and any person involved in the design of antennae can address this easily.

[0045] A second practical variant is shown in figure 7 so that, in this case, the three central beams (array 3b, 3c, 3d) are implemented with a smaller horizontal beam width and with pointing directions closer to each other, and the end beams with greater horizontal beam width and more distant beams. This distribution achieves the radiation diagram shown in figure 8. This practical case manages to increase the two end sectors of the cell, where the population density decreases.

[0046] In this invention two-dimensional arrays 3a, 3b, 3c, 3d and 3e of radiating elements 2 have been shown, where the number of elements in a vertical direction is 2. The vertical array factor achieved with 2 radiating elements gives us a vertical beam width of around 35 degrees, which depends fundamentally on the distance between elements, amongst other factors. As a practical implementation, a beam width of 30 degrees has been selected.

[0047] Figure 9 shows the vertical radiation diagram of the antenna constructed under the first variant of practical execution of radiating elements relating to those shown in figures 3 and 4.

[0048] In contrast, one-dimensional arrays with an approximate vertical beam of 60 degrees can be selected, or arrays with three or more radiating elements in a vertical direction, further reducing the beam width but increasing the complexity and size of the antenna.

[0049] Two radiating elements in a vertical direction is the best compromise solution between beam width and antenna size. In the practical case of this invention of five beams with gains greater than 20dBi per beam in the 1710-2690MHz band, the size of the antenna is reasonable, at 1100 x 1300mm (figure 10). The vertical beam width of 30 degrees also has the advantage of giving very good coverage to a whole stand in a football stadium with no need to offer electrical tilt, thus simplifying the overall scheme of the antenna. Nevertheless, the antenna can be installed with mechanical tilt if so wished, without degrading the radiation diagram thanks to the broad vertical band width.

[0050] A third practical execution is shown in figure 11, where two one-dimensional arrays, 3a and 3e, have been added, to give coverage to the ends of the cell with smaller population density, thus increasing the coverage area without adding complexity to the antenna. The advantage of this embodiment compared to the one shown in figure 7 is the reduction in antenna size, at the expense of increasing the vertical beam width of the end beams.

[0051] With the explanations given above, the reader can infer multiple possible combinations for implementation subject to this invention.

[0052] Figure 12 shows a diagram of the mechanism given to the multibeam antenna which is the object of this invention, for remote adjustment of the azimuth pointing direction for each of the beams forming the antenna. As a general rule, the mechanism is composed of an electronic module 9 and as many mechanical drive modules 8a, 8b, ..8e as there are phase shifters 5a, .. 5e in the antenna; this is five in the practical embodiment which concerns us here.

[0053] The electronic module 9 is responsible for communications with the management node 90, for receiving the commands ordering adjustment of the beams and interpreting said commands, activating the relevant control signals to activate the mechanical devices 8 responsible for moving the parts of the phase shifters 5. In order to ensure interoperability between different manufacturers, the communications between the electronic module and the control centre adhere to the specifications defined in the standard "AISG Extension: Remote Azimuth Steering, Standard No. AISG-ES-RAS v2.2.0", but is not limited to this. This invention is open to any other communication protocol between control entity and controlled entity.

[0054] The electronic module 9 controls the mechanical means which activate the movement of the elements of the phase shifters 5, the displacement of which varies the phase given to the radiating elements 2 of the array 3a, 3b, ... and thus the beam pointing direction.

[0055] Figure 13 shows the mechanical drive mechanism which has been given to this practical embodiment, comprising a motor 10 and a transmission mechanism formed of gears 11 which transfer the movement of the motor 12 shaft to the bar 13 attached to the phase shifters. In practice, any mechanism used for remote control of the electrical tilt of the antennae can be adapted without supposing any invention.

[0056] In the practical materialisation of this invention, the means for adjusting the azimuth have been arranged as a system integrated in the antenna, where both the electronic module and the mechanical drive systems and motors are inside the same radome housing the antenna. Nevertheless, it can be arranged both inside and outside, without supposing any novelty to that presented in this invention.

[0057] The azimuth adjustment mechanism has been designed to be activated both manually and remotely, as currently known in tilt adjustment systems.

[0058] The azimuth adjustment mechanism includes an indicator 14, visible from the outside, which signals the azimuth configured for each beam.

[0059] In this invention, a solution is provided for this need by proposing an embodiment of the multibeam antenna with dynamically configurable azimuth pointing directions and reduced beam widths, while maintaining the general features for base station antennae, such as isolation between polarisations and between 30dB beams.

[0060] All of this achieves optimum sectoring of the cell for events attended by large crowds, such as concerts or in sports stadiums.

Claims

1. A multibeam antenna for mobile telephone base station, **characterised in that** the multibeam antenna (1) comprises:

    a. a two-dimensional matrix of radiating elements (2) with dual polarization;

    - the radiating elements (2) are each grouped together into one-dimensional or multi-dimensional arrays (3a, 3b, ..) in a horizontal or azimuthal direction;
    - each array (3a, 3b, ..) of the radiating elements (2) form a radiation beam of the multibeam antenna;
    - the number of beams is modular and easily scalable through modular incorporation of arrays (3a, 3b, ..) of the radiating elements (2);

    b. as many pairs of radio-frequency signal entry ports (6) as beams;

    - the signal from each pair of radio frequency ports is distributed in power and phase in an array (3a, 3b, ..) of radiating elements (2) by means of distribution networks (5), also called beamforming networks or phase shifters;

    c. the different arrays (3a, 3b, ..) of radiating elements (2) and the distribution networks are totally independent of each other in radioelectric terms;
    d. the vertical and horizontal beam widths of each beam of radiating elements can be personalised and optimised independently of the remaining beams;
    e. each distribution network or phase shifter (5) has moving parts which vary the phase given to the radiating elements (2), allowing the azimuth angle of each array (3a, 3b, ..) to be varied dynamically in a completely independent manner.

2. A multibeam antenna for mobile telephone base station, according to claim 1, **characterised in that** the radiating elements of the matrix are five two-dimensional arrays (3a, 3b, 3c, 3d, 3e) in 2x12 composition, presenting an azimuthal beam width at half power of 7 degrees, and nominal beam pointing directions of 0, +7, +14, -7 and -14 degrees, in which each beam can be varied by +/-5 degrees compared to its nominal position, and independently of the rest.

3. A multibeam antenna for mobile telephone base station, according to claim 1, **characterised in that** the radio frequency signal present in each of the entry ports (6) passes through a first power and phase distribution network (5) which distributes the signal in a horizontal direction, where each of the outputs from this first distribution network (5) passes through a second distribution network (7) which distributes the power and phase in a vertical direction, where each of the outputs in this second distribution network (7) attacks one radiating element (2).

4. A multibeam antenna for mobile telephone base station, according to claim 3, **characterised in that** each array (3a, 3b, ...) comprises two radiating elements (2) in a vertical direction, where the second distribution network (7) is a simple "T" shaped network which shares the power equally between the two radiating elements and provides the same phase to both radiating elements, providing a 0 degree electrical tilt of the beam.

5. A multibeam antenna for mobile telephone base station, according to claim 3, **characterised in that** each array (3a, 3b, ...) comprises two radiating elements (2) in a vertical direction, where the second distribution network (7) is a simple "T" shaped network which shares the power equally between the two radiating elements and provides the same phase to both radiating elements (2), providing a fixed electrical tilt of something other than 0 degrees.

6. A multibeam antenna for mobile telephone base station, according to claim 3, **characterised in that** each array (3a, 3b, ..) comprises three or more radiating elements (2) in a vertical direction, where the second distribution network (7) shares the power and phase between the radiating elements, generating an array factor in the vertical direction which defines the form and tilt of the overall beam in a vertical direction.

7. A multibeam antenna for mobile telephone base station, according to claim 1, **characterised in that** all the second distribution networks (7) present at the output of a first distribution network (5) must be equal to each other to ensure that the beam generated by the two-dimensional array grouping (3a, 3b, ..) is not degraded.

8. A multibeam antenna for mobile telephone base station, according to claim 1, **characterised in that** the mechanisms provided for the control of the azimuth directions may be internal or external to the multibeam antenna.

9. A multibeam antenna for mobile telephone base station, according to claim 1, **characterised in that** the mechanisms provided for the control of the azimuth directions comprise an electronic module (9) which communicates with a control centre and at least one mechanical module, the movement of which is controlled by the electronic module (9).

10. A multibeam antenna for mobile telephone base station, according to claim 9, **characterised in that** the mechanical module comprises a motor (10) which transfers the rotating movement of its drive shaft (12) to the bar (13) attached to the distribution network (5) by gears (11), where said mechanical modules are attached to the electronic module (9) by cables connected to both connectors of the electronic module and the motor (10) of the mechanical module.

11. A multibeam antenna for mobile telephone base station, according to claim 10, **characterised in that** the mechanisms for adjusting the azimuth of the array can be operated both manually and remotely, showing at all times the indication of the real adjustment of the azimuth of each beam by means of an indicator (14).

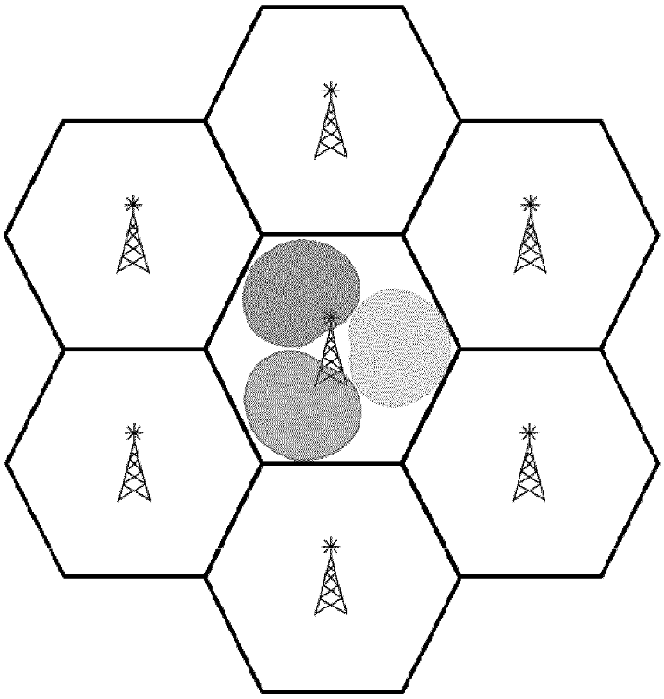


FIG. 1

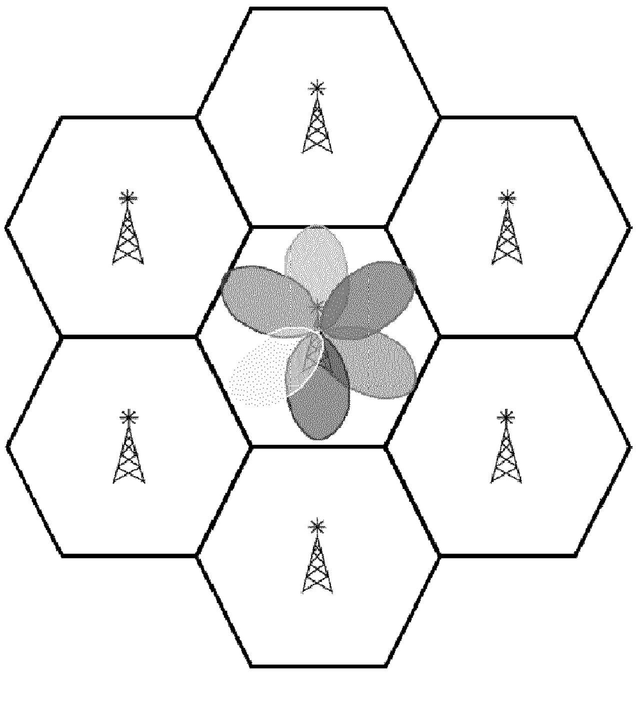
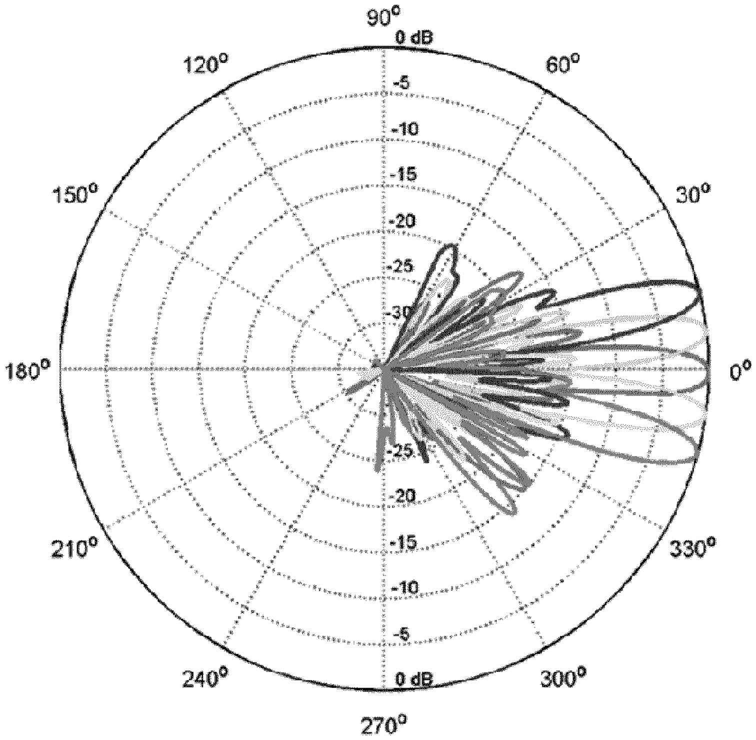


FIG. 2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-5
-10
-15
-20
-25
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120°
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30°
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0°
210°
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240°
300°
270°
0 dB

FIG. 3

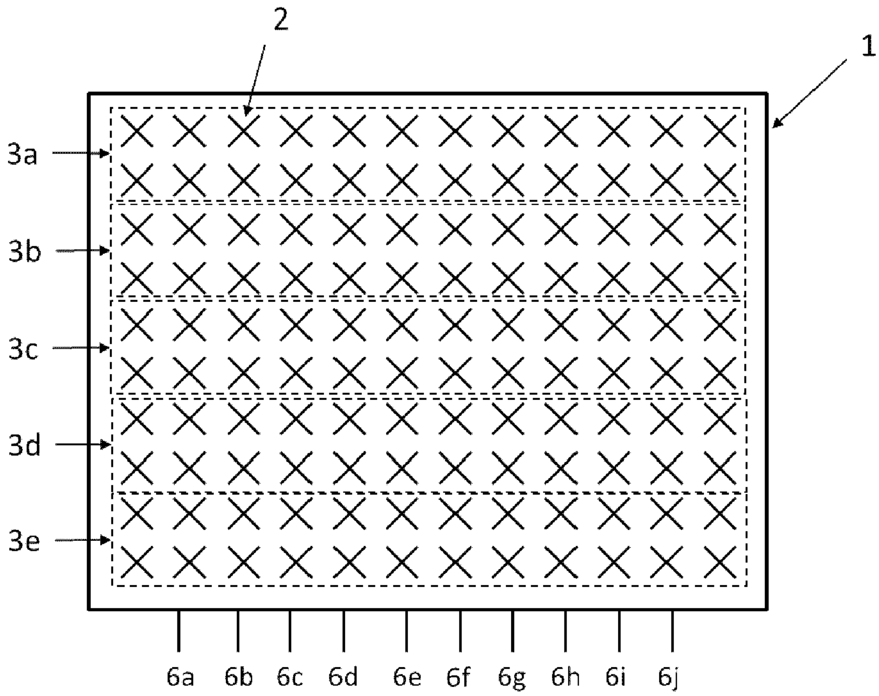
2
1
3a
3b
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FIG. 4

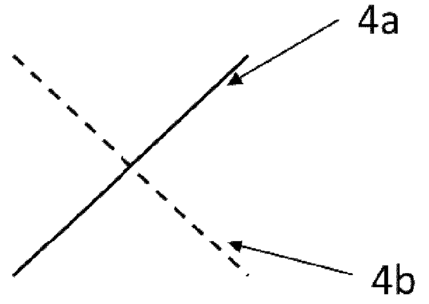

FIG. 5

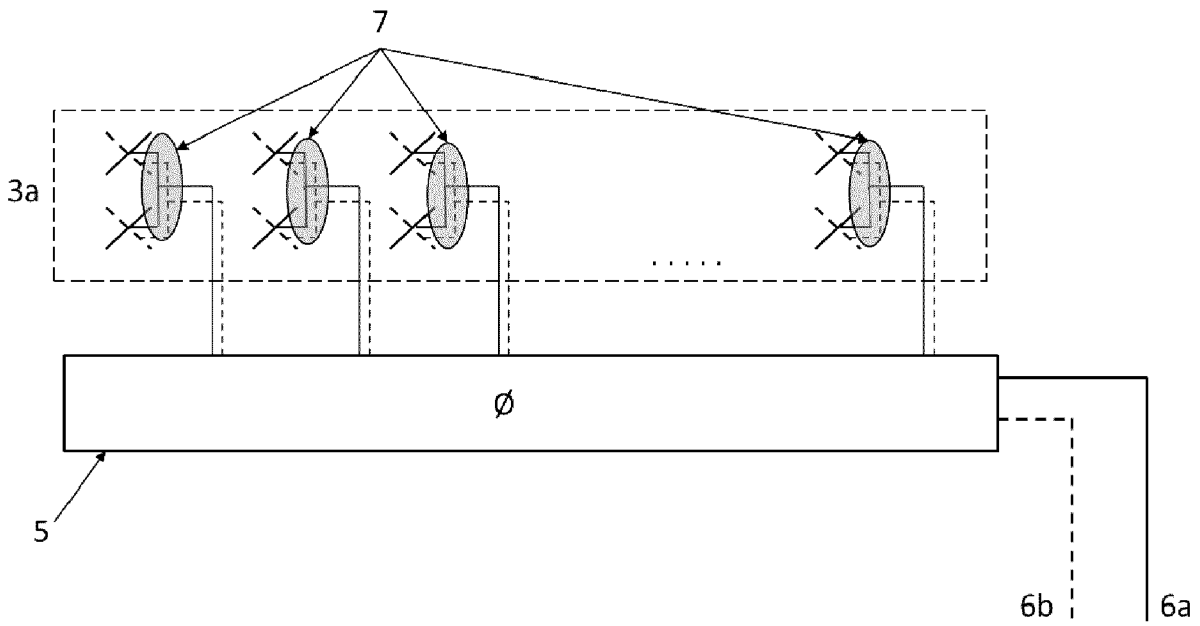

FIG. 6

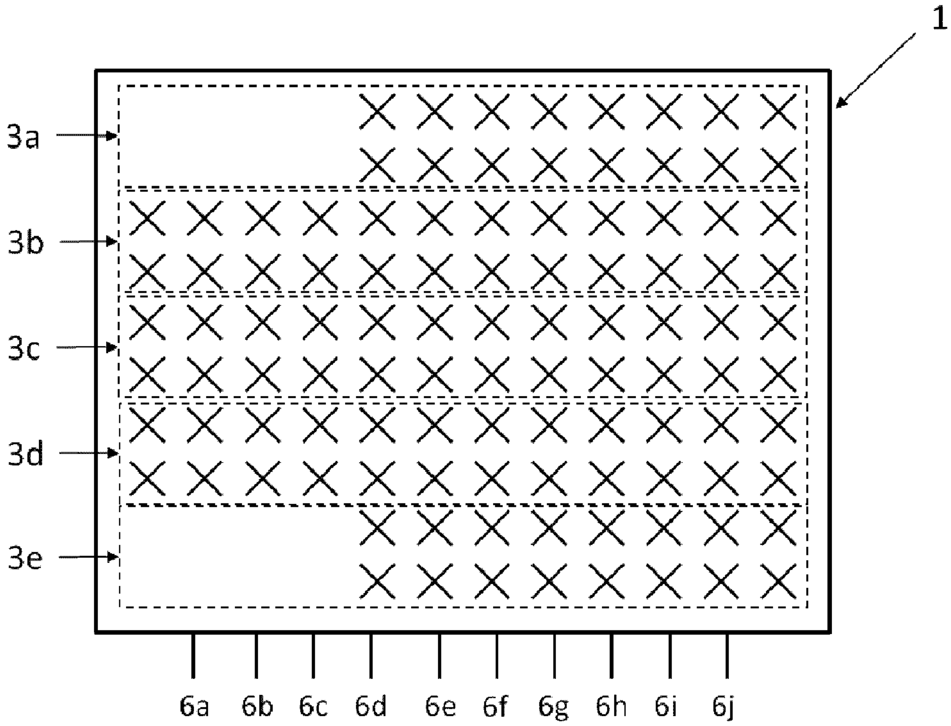
1
3a
3b
3c
3d
3e
6a
6b
6c
6d
6e
6f
6g
6h
6i
6j

FIG. 7

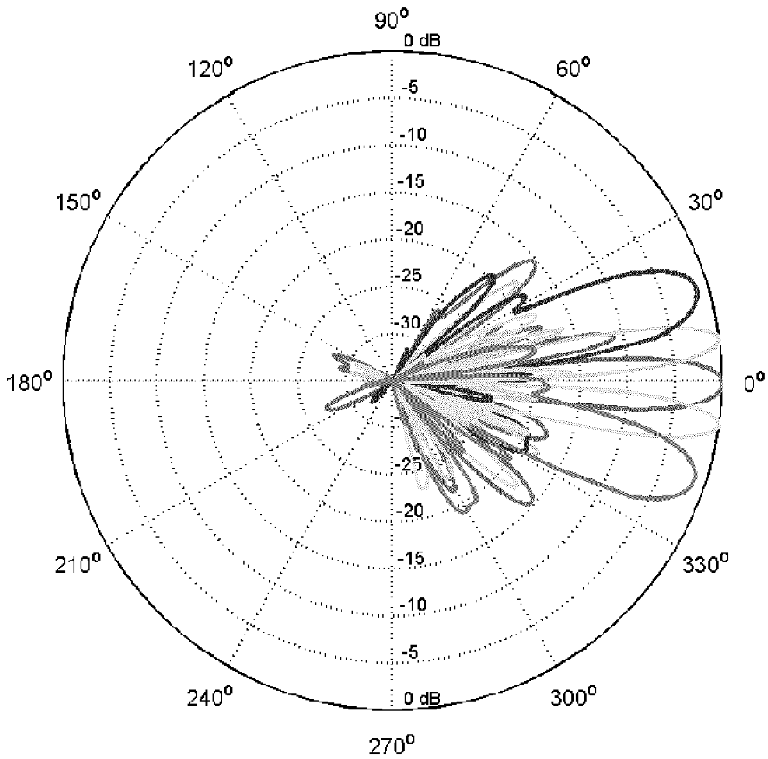
90°
0 dB
120°
60°
-5
-10
-15
150°
30°
-20
-25
-30
180°
0°
-25
-20
-15
210°
330°
-10
-5
0 dB
240°
300°
270°

FIG. 8

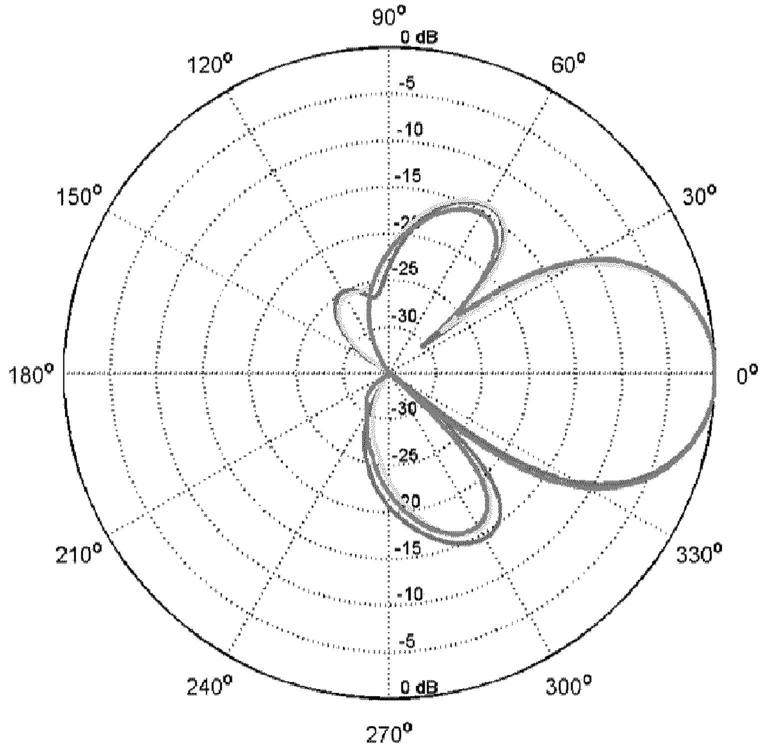
90°
0 dB
120°
60°
-5
-10
150°
-15
30°
-25
-30
180°
0°
-30
-25
-15
-10
210°
330°
-5
240°
0 dB
300°
270°

FIG. 9

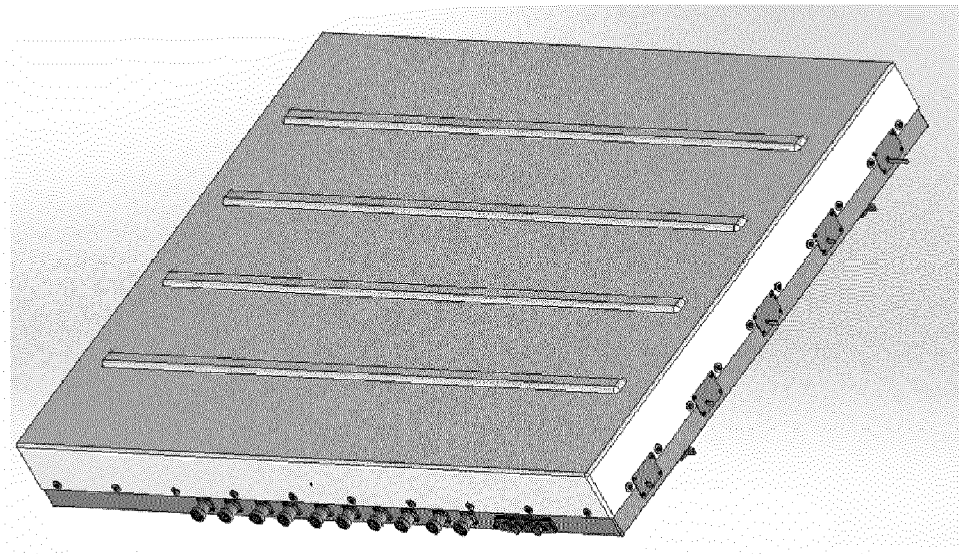

FIG. 10

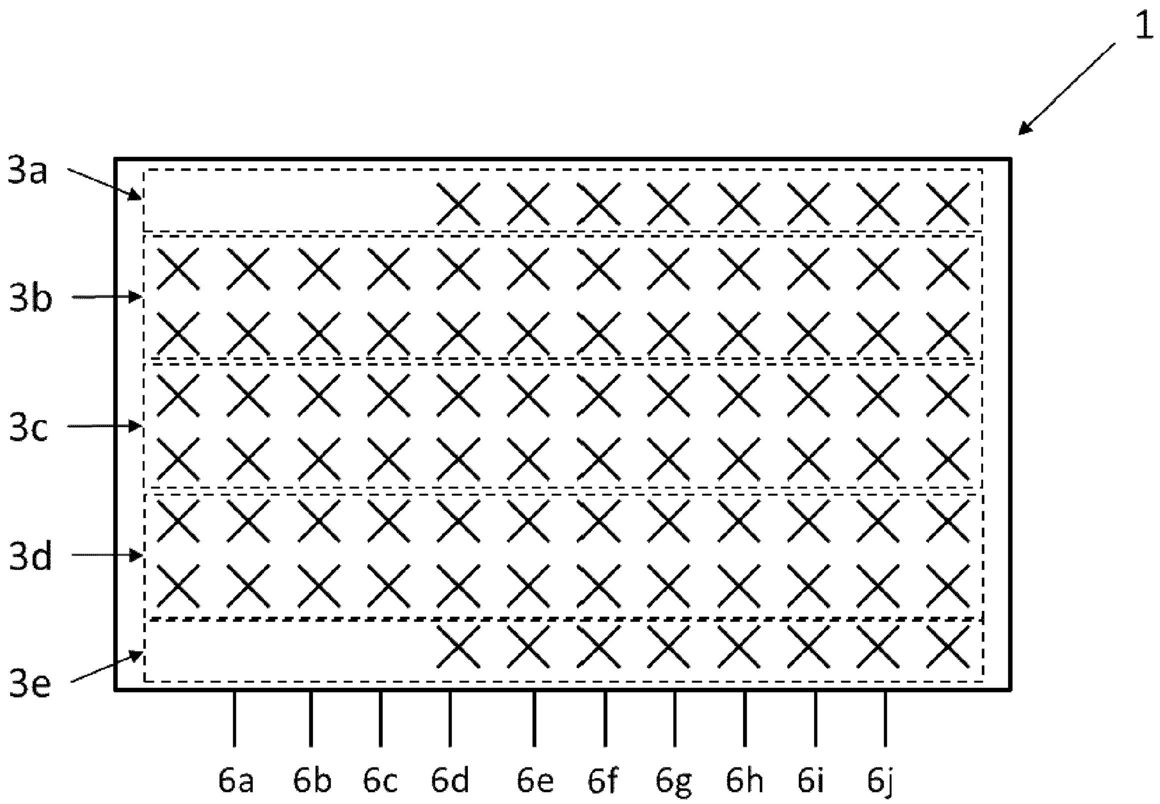

FIG. 11

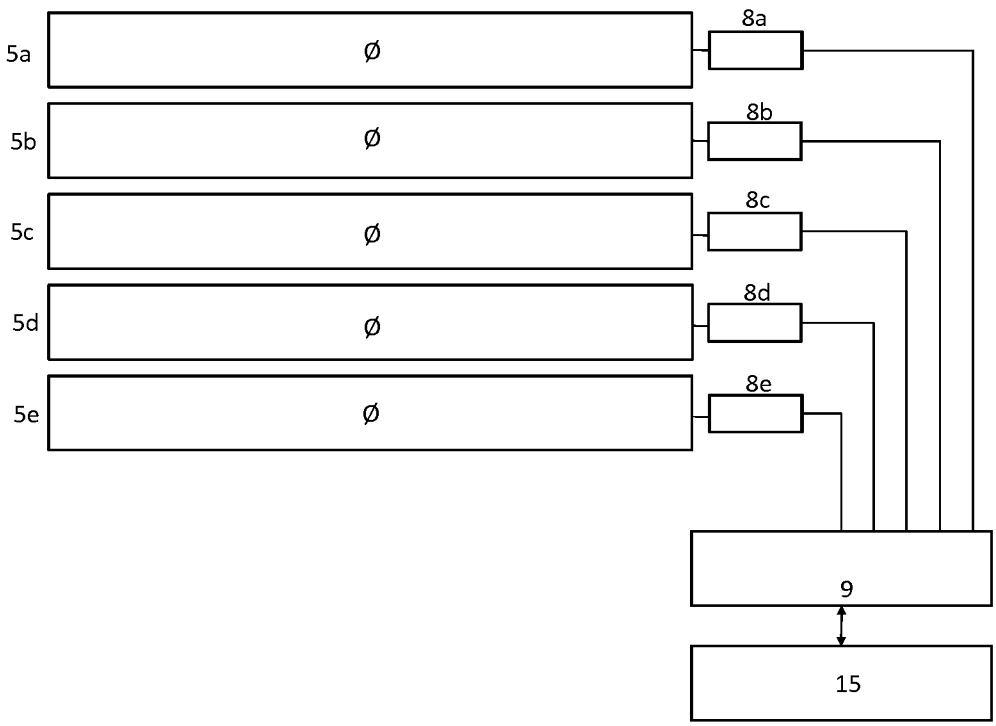

FIG. 12

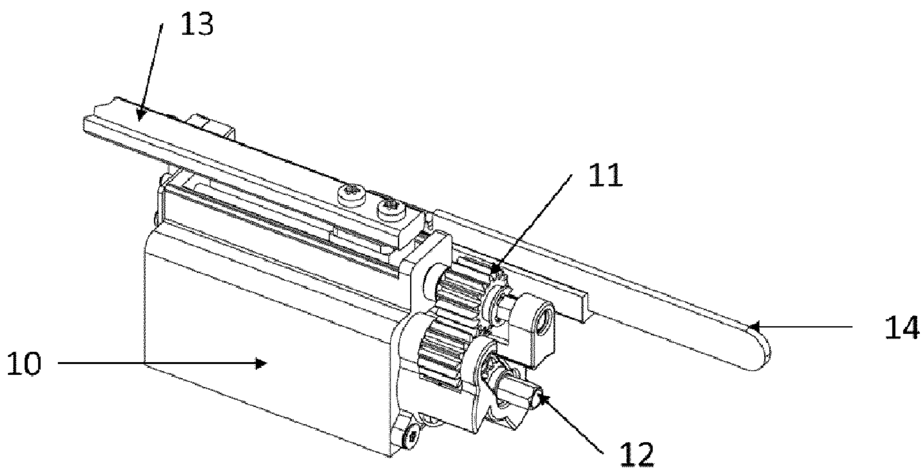

FIG. 13

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 8138

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	22 November 2016	Sípal, Vít

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