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(54) **Adaptive antenna and a method of controlling an adaptive antenna beam**

(57) An adaptive antenna, comprising at least two modules (H1, H2) and at least one column of radiators (1) arranged on each of the antenna modules, characterised in that the modules (H1 and H2) are arranged edgewise next to each other and each of the modules has at least 8 radiators (1) along a vertical axis of the module (H1, H2). The resulting axes of antenna azimuths divide a 120° angular sector into equal sectors.

A method consists in that the beam is modified and

the modulated LTE signal is transmitted. CQI value is determined by means of UE, the CQI being transmitted in UL return channel to all elements of the antenna. By means of BBU, a path corresponding to the highest CQI which is optimal for the beam is chosen. The modulated LTE signal is multiplied by controlling vectors [K] and [L] of a multiplier system in an RRH module, and then it is transmitted to the power divider (2), and subsequently to the radiators (1) of one polarisation.

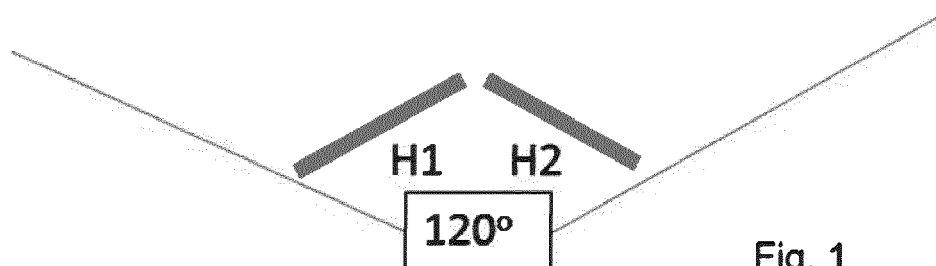


Fig. 1

Description

[0001] The object of the invention is an adaptive antenna, with beam forming in the vertical plane and switching of the beam in the horizontal plane, especially for the 1800 MHz band. The object of the invention is also a method of controlling the adaptive antenna beam.

[0002] From the prior art, prototypes of active antennas with a possibility of controlling the beam in the vertical plane are known. Such an antenna is constituted by an antenna-array, usually of 10-12 elements. The height of such antennas for the 1800 MHz band is approximately 1.2-1.4 m, which is associated with the requirements to observe expected functional parameters, i.e. gain and directivity of the antenna. EP 2341577 A1 application discloses an antenna array, wherein the control of the radio beam is realised by means of mechanical systems. Furthermore, the apparatus enables beam forming by modifying the power supply parameters of the apparatus. The relevant adjustment of these parameters allows to modify amplitude, phase and delay of power supply signal components powering the corresponding elements of the apparatus. Thus, the shape of the forming beam can be modified. Patent application WO 2013024852 A1 discloses a communication system, comprising an antenna array, with multiple antenna elements disposed in a single direction. The communication system comprises a base station, adapted for forming a plurality of radio beams for vertical sectoring. The system uses a feedback signal, comprising information on channel quality, and the information comprised therein is used for forming a beam in the vertical plane.

[0003] In turn, patent specification EP 2482582 B1 discloses a base station configured for controlling at least one antenna system which comprises multiple antenna elements, at least two antenna elements being arranged in various vertical positions in relation to the virtual horizontal plane. The base station is adapted for transmitting specific pilot signals on orthogonal radio resources through different antenna elements. Further, the base station is adapted to receive feedback information from a terminal. The feedback information characterises a difference in phase between pilot signals, which was registered by the terminal and is used for determining a tilt angle of radio beams transmitted to the terminal or from the terminal. According to the solution, vertical sectoring of the cell, which is realised by an appropriate vertical arrangement of the antenna elements, is provided. The feedback information does not contain data on the channel quality.

[0004] Patent application US 20110103504 A1 discloses a method allowing generation of two radio beams, constituting a virtual antenna, which can be individually tilted in the vertical plane by means of physical antennas. The so constituted virtual antennas transmit pilot signals to the user equipment UE. The invention aims to improve coverage of the cell and to increase spectral efficiency on its borders. Beam forming is realised based on feed-

back information obtained, from a mobile terminal, based on the difference in phase of pilot signals, with the use of a codebook for 2 and 4 layers.

[0005] The aim of the invention is to increase network capacity for the channel from the base station to the terminal, the user equipment UE, and to provide control of the beam in the horizontal plane, while maintaining the shape of the radiation pattern and functional parameters, especially the required level of side lobes. The solution proposed enables effective control of the beam in the horizontal plane, provides a wide angle of changes in propagation directions and stability of radiation pattern. Further, an adaptive solution for horizontal and vertical planes has been combined in an innovative way. The solution provides reduction of the interference level, increase in operating directivity of the antenna - PD-SCH signal is transmitted in the direction where the terminal is located, and not, as before, within the entire sector. The solution provides a significant increase in the network capacity in the channel to the terminal. The solution proposed simplifies the antenna construction, and thereby the space required for installation is reduced, and at the same time reduces manufacturing costs of the antenna, while maintaining the expected parameters.

[0006] The solution proposed is not limited to the 1800 MHz band, it can also be used in WCDMA and LTE networks, more specifically, in the B3/B7/B20 (FDD) bands. Versatility of the antenna structure combined with switching the beam in the horizontal plane is possible in WCDMA applications. Introduction of the invention into the networks operating over the 1800 MHz band allows increase in the network capacity, while reducing the size of the antenna.

[0007] The adaptive antenna according to the invention is characterised in that the antenna modules are arranged edgewise next to each other and each of the modules has at least eight radiators arranged along the vertical axis of the antenna module and at the same time symmetrically with respect to the horizontal axis of the antenna module, wherein the resulting axes of antenna azimuths divide a 120° angular sector into equal parts.

[0008] Preferably, the radiator comprises at least two dipoles, additionally preferably the dipoles are orthogonally polarised relative to each other.

[0009] Preferably, each of the antenna modules comprises two columns of radiators arranged symmetrically along the vertical axis of the antenna module and at the same time symmetrically with respect to the horizontal axis of the antenna module.

[0010] It is also preferable for the antenna to comprise two modules H1 and H2, and the resulting axis of the antenna azimuth divides the 120° angular sector into two sectors, each of 60°, wherein the axes of the main radiation beam of modules H1 and H2 are arranged at an angle of 30°, with a tolerance of $\pm 5^\circ$, starting from the edge of the sector.

[0011] Preferably, the antenna comprises three antenna modules, and the resulting axes of the antenna azi-

muths divide the 120° angular sector into three sectors, each of 40°, wherein the axes of the main radiation beam of the external modules of the antenna are arranged at an angle of 20°, with a tolerance of $\pm 3^\circ$, starting from the edge of the sector, and the main axis of the radiation beam of the internal module is arranged at an angle of 60°, with a tolerance of $\pm 3^\circ$, starting from the edge of the sector.

[0012] Preferably, the antenna comprises four antenna modules, and the resulting axes of the antenna azimuths divide the 120° angular sector into four sectors, each of 30°, wherein the axes of the main radiation beam of the external modules of the antenna are arranged at an angle of 15°, with a tolerance of $\pm 2^\circ$, starting from the edge of the sector, and the main axes of the radiation beam of the internal modules are arranged at an angle of 45°, with a tolerance of $\pm 2^\circ$, starting from the edge of the sector.

[0013] It is also preferable for the height of the antenna modules to be lower than 80 cm, and for the width of the entire antenna to be lower than 35 cm.

[0014] In addition, it is preferable that the radiators of one polarisation of one module are combined in pairs and are powered by power dividers 1:2 or 1:3, or 1:4.

[0015] Method of controlling an adaptive antenna beam according to the invention is characterised in that, by means of BBU, CSI-RS indicators are assigned to each one of at least 4 paths of the antenna modules, then these indicators are transmitted in DL channel to the UE and, by means of the UE, CQI value is determined based on the received CSI-RSs, the said CQI being, by means of the beam in the UL return channel, subsequently transmitted to all elements of the antenna, wherein an orthogonally polarised signal, included in the beam, is summed in the divider, and, by means of CPRI interfaces, it is transmitted to BBU, and then this signal is demodulated by means of BBU, and based on CQI, by means of BBU, a path corresponding to the highest CQI which is optimal for the beam is chosen, and the modulated LTE signal, comprising PDSCH logical channel data is multiplied by controlling vectors [K] and [L] of a multiplier system in RRH module, and then the signal is processed in a D/A converter, and then the signal is forwarded to an amplifier, where it is amplified, and further transmitted to the power divider, and subsequently to the radiators of one polarisation.

[0016] Preferably, the beam in DL and UL direction is transmitted with the use of radiators having polarisations of +45° and -45°.

[0017] It is preferable that dipoles are used as the radiators.

[0018] Preferably, for the internal sector of the cell, PDSCH 1 logical channel is used, and for the external sector of the cell, PDSCH 2 channel is used.

[0019] Preferably, power dividers 1:2 or 1:3, or 1:4 are used as the power dividers.

[0020] Also preferably, by means of SON located in BBU, controlling vectors [K] and [L] are dynamically controlled.

[0021] The object of the invention is shown in the drawing in which Fig. 1 shows a schematic plan view of an adaptive antenna with two modules, Fig. 2 - a schematic plan view of an adaptive antenna with three modules, Fig. 3 - a schematic plan view of an adaptive antenna with 4 modules, Fig. 4 - schematic front and side views of one of antenna modules together with radiators, Fig. 5 - a system implementing a method according to the invention Fig. 6 - horizontal transmission-reception radiation pattern of a single antenna module, Fig. 7 - vertical transmission-reception radiation pattern of a single antenna module, Fig. 8 - vertical radiation patterns for tilts of -5° and -10°.

[0022] The adaptive antenna can be used in WCDMA and LTE systems.

[0023] The adaptive antenna in one embodiment has a height of 72.2 cm and a width of 33 cm, and comprises two antenna modules H1 and H2 arranged edgewise next to each other, having a height of 72.2 cm and a width of 16.3 cm each. The resulting axis of the antenna azimuth divides the 120° angular sector into two equal sectors of 60° each. The main axes of the radiation beam of particular antenna modules H1 and H2 are arranged at an angle of 33.4°, starting from the edge of the 120° angular sector. This means that antenna modules H1 and H2 are used in directions of $\pm 26.6^\circ$, which enables a wide range of changes in beams in plane H of 53.2°.

[0024] In another embodiment, the adaptive antenna comprises three modules H1, H2 and H3, arranged edgewise next to each other. The resulting axes of the antenna azimuths divide the 120° angular sector into three equal sectors of 40° each.

[0025] In a further embodiment, the adaptive antenna comprises four modules H1, H2, H3 and H4 arranged edgewise next to each other. The resulting axes of the antenna azimuths divide the 120° angular sector into four equal sectors of 30° each.

[0026] Each of modules H1 and H2 of the adaptive antenna with two modules has eight radiators 1 arranged along the vertical axis of each antenna module H1 and H2 and at the same time symmetrically with respect to the horizontal axis of antenna modules H1 and H2. First two radiators 1, viewed from the top of antenna modules H1 and H2, are spaced from each other by 9 cm, and from another, second pair of radiators 1 by 10.9 cm. The second pair of radiators 1 is constituted by two radiators 1 spaced from each other also by 9 cm. The next two pairs of radiators 1 are arranged on antenna module H1 symmetrically to the first two pairs of radiators 1 with respect to the horizontal axis of antenna module H1. The radiators 1 closest to the horizontal axis are spaced from it by 3.6 cm, i.e. the distance between them is 7.2 cm. The radiators 1 have a diameter of 1.3 cm and are spaced from modules H1 and H2 by 5.4 cm, and the whole mounting of radiators has a width of 9.1 cm.

[0027] In another embodiment, each of antenna modules H1 and H2 has two columns, 8 radiators 1 each, arranged symmetrically on both sides of the vertical axis

of antenna modules H1 and H2.

[0028] In one embodiment, radiators 1 are powered directly by the power supply systems. With a larger number of bays (tiers), the radiators 1 (dipoles) can be combined in pairs powered jointly by a coaxial power divider 2 1:2 with wave impedances of input and outputs, matched to wave impedances of wires connected to input and outputs of the power divider 2. In other embodiments, power dividers 2 1:3 or 1:4 are used. In particular, the power divider can be realised on coaxial cables having wave impedances matched by a matching network. Wave impedance at the antenna inputs is 50 W, obtained if necessary by an impedance transformer realised via a coaxial cable section having its wave impedance and length matched.

[0029] All the radiators 1 are powered by coaxial cables of a wave impedance matched to the wave impedance of the radiators 1 (dipoles).

[0030] In one embodiment, antenna modules H1 and H2 can be powered by radiators of linear polarisation. In another embodiment, each radiator 1 comprises two orthogonally polarised dipoles, preferably with a polarisation of $\pm 45^\circ$.

[0031] Method of controlling an adaptive antenna beam with orthogonally ($\pm 45^\circ$) polarised radiators 1 consists in that, by means of BBU (base band unit) decision unit, for each of 4 paths of antenna modules H1 and H2, i.e. for internal and external sectors of module H1 and for internal and external sectors of antenna module H2, CSI-RS (cell specific indicator reference signal, compliant with the standard Rel 10) indicators are assigned. Then, CSI-RS indicators are transmitted in DL (downlink) channel to the user equipment UE, every 10 frames in slot number 2. In the user equipment, based on the received indicators, CQI (cell quality indicator) value is determined, and this indicator is transmitted in UL (uplink) channel to NodeB, i.e. RRH (radio remote head) and BBU. The indicator included in the transmitted signal is received by all elements of the antenna. Due to the polarisation used, 8 paths (4 paths and each in two polarisations of $\pm 45^\circ$) arrive from the UE to the antenna. Then, orthogonally polarised signal, received in the beam, is summed in the power divider 1 1:2, and by means of 4 CPRI (common public radio interface) interfaces, performed on optical fibres, 2 interfaces for one antenna module, it is transmitted to BBU, where it is demodulated. In the next step, BBU, based on CQI received in the signal, selects an optimal transmission path which matches the highest CQI, wherein CQI is in the range of 1 to 15. Modulated LTE signal comprising data of PDSCH (physical downlink shared channel), PDSCH1 for the internal sector of the cell and PDSCH2 for the external sector of the cell, respectively, is multiplied by controlling vectors [K1, K2, K3, K4] and [L1, L2, L3, L4]. Vectors [K] and [L] are responsible for the tilt of internal and external beams for each antenna module H1 and H2. The tilt of the beam of 5° is realised by progressive shift of power supply phase with a progression of 17° , i.e. the first bay- 0° , the

second bay+ 17° , the third bay+ 34° , etc. Whereas, the tilt of the antenna beam by 10° represents a progression of 34° .

[0032] Controlling vectors [K] and [L] are determined in the optimisation process. Their value is predefined beyond the standardised process of LTE signal processing. Vector values are selected based on drive-tests, i.e. on radio measurements, and are made dependent on the surrounding environment. The determined predefined values, which are subject to the optimisation process and are corrected by crews that integrate the network, are assigned.

[0033] After the multiplication, a phase shifted signal is obtained, which is then processed from digital to analogue form in the D/A converter and is transferred to the amplifier 3, where the signal is amplified and transmitted to the power divider 2 1:2 and to the radiators 1 of one polarisation. The radiators 1 comprise two orthogonally polarised dipoles with polarisations of $\pm 45^\circ$, thereby, each of the dipoles is individually powered by a system of powers divider 2 1:2, a D/A converter, an antenna matching network and an amplifier.

[0034] In other embodiments, power dividers 1 1:3 or 1:4 are used, then radiators of one polarisation from one antenna module are grouped.

[0035] In another embodiment, controlling vectors [K] and [L] are controlled by means of SON (self-optimising network). Then, the selection of angle of sector tilts is realised dynamically. SON, functionality of which is realised by BBU, actually uses features of the antenna as a fully adaptive antenna. Algorithms for determining vector values [K] and [L] constitute an integral part of the processes controlled by SON. BBU without SON takes a decision related to the allocation of PDSCH channel to the right path but does not modify it. In an example using SON, through the control of vectors [K] and [L], available paths can be dynamically modified.

[0036] In another embodiment, the final, additional tilt of the beam is realised by a RET (remote electrical tilt) module in which the signal before being passed to the power divider 1 is multiplied by a constant value.

[0037] Due to the use of the signal polarisation in DL and UL channels, in addition to the main transmission path, corresponding to the highest CQI, an alternative path of vertical sectoring is possible in the method according to the invention as the remaining vector [K] and [L] is used for multiplying the signal and for forming an alternative receiving channel analogously to the main path. Analogously, the signal received by the module is subjected to the same processing as for the main module H1. As a result, two other alternative paths are provided for UL channel having two orthogonal polarisations.

[0038] In an embodiment in which the beam control relates to an antenna comprising two modules H1 and H2, a joint transmission of PDSCH1 and PDSCH2 on antenna module H1 is possible, in the absence of transmission on antenna module H2.

[0039] In another embodiment, module H1 does not

transmit the signal, but antenna module H2 transmits PDSCH1 together with PDSCH2.

[0040] In a further embodiment, antenna module H1 transmits PDSCH1, and antenna module H2 transmits PDSCH2.

[0041] In yet another embodiment, antenna module H1 transmits PDSCH2, and module H2 transmits PDSCH1.

[0042] For an adaptive antenna with two modules H1 and H2, an embodiment in which module H1 is the leading module is possible. In this case, horizontal radiation pattern of each module are in the range of $65 \pm 5^\circ$ for HPBW -3dB. The leading module H1 is selected for the transmission of control channels. Module H1 is the leading module, operates on the basis of conventional principles of passive antenna, and in particular transmits information of logical control channels. Whereas, for PDSCH logical channels, module H1 or H2 and dedicated tilt of the beam are selected. Data channels, including PDSCH, are transmitted according to the method of the invention.

[0043] Due to the need to select a path for control channels, providing coverage for the entire sector in the case of implementing the adaptive antenna on more than two modules or in the case the horizontal radiation patterns of the modules are narrower than 60° (HPBW -3dB), a joint transmission by the selected modules is used. Thus, for two modules, this is a joint transmission on modules H1 and H2.

[0044] For example, with an antenna comprising three modules H1, H2 and H3, possible transmission configurations include a joint transmission on modules H1, H2 and H3, transmission on modules H1 and H3, and transmission on module H2, if radiation patterns of the modules are diversified and if module 2 meets the criteria of $65^\circ \pm 5^\circ$ for HPBW -3dB.

[0045] Method of controlling the beam can be also used in adaptive antennas comprising more than two antenna modules. Then, for the method using an antenna with 4 modules, possible configurations include a joint transmission on modules H1, H2, H3 and H4, transmission on modules H1, H3, transmission on modules H2 and H4, and transmission on modules H2 and H3. For data channels, a cyclic switching of beams according to the method of the invention is used.

Claims

1. An adaptive antenna, comprising at least two antenna modules and at least one column of radiators on each of the antenna modules, **characterised in that** the antenna modules (H1, H2) are arranged edge-ways next to each other and each of the modules (H1, H2) has at least 8 radiators (1) arranged along a vertical axis of the antenna module (H1, H2) and at the same time symmetrically with respect to a horizontal axis of the antenna module (H1, H2), wherein the resulting axes of antenna azimuths divide a 120°

angular sector into equal parts.

2. The antenna according to claim 1, **characterised in that** the radiator (1) comprises at least two dipoles.
3. The antenna according to claim 2, **characterised in that** the dipoles are orthogonally polarised relative to each other.
4. The antenna according to any one of the preceding claims, **characterised in that** each of the antenna modules (H1, H2) comprises two columns of radiators (1) arranged symmetrically along the vertical axis of the antenna module (H1, H2) and at the same time symmetrically with respect to the horizontal axis of the antenna module (H1, H2).
5. The antenna according to claim 1, **characterised in that** it comprises two modules (H1, H2), and the resulting axis of the antenna azimuth divides the 120° angular sector into two sectors, each of 60° , wherein the axes of the main radiation beam of the modules (H1 and H2) are arranged at an angle of 30° , with a tolerance of $\pm 5^\circ$, starting from the edge of the sector.
6. The antenna according to claim 1, **characterised in that** it comprises three antenna modules (H1, H2, H3), and the resulting axes of the antenna azimuths divide the 120° angular sector into three sectors, each of 40° , wherein the axes of the main radiation beam of the external modules (H1 and H3) of the antenna are arranged at an angle of 20° , with a tolerance of $\pm 3^\circ$, starting from the edge of the sector, and the main axis of the radiation beam of the internal module (H2) is arranged at an angle of 60° , with a tolerance of $\pm 3^\circ$, starting from the edge of the sector.
7. The antenna according to claim 1, **characterised in that** it comprises four antenna modules (H1, H2, H3, H4), and the resulting axes of the antenna azimuths divide the 120° angular sector into four sectors, each of 30° , wherein the axes of the main radiation beam of the external modules (H1 and H4) of the antenna are arranged at an angle of 15° , with a tolerance of $\pm 2^\circ$, starting from the edge of the sector, and the main axes of the radiation beam of the internal modules (H2, H3) are arranged at an angle of 45° , with a tolerance of $\pm 2^\circ$, starting from the edge of the sector.
8. The antenna according to claim 1, **characterised in that** the height of the antenna modules (H1, H2) is lower than 80 cm, and the width of the entire antenna is lower than 35 cm.
9. The antenna according to claim 1, **characterised in that** the radiators (1) of one polarisation of one mod-

ule (H1, H2) are combined in pairs and are powered by power dividers (2) 1:2 or 1:3, or 1:4.

10. A method of controlling an adaptive antenna beam in which, by means of radiocommunication network elements, such as a mobile terminal UE, an RRH control module together with a multiplier system, a BBU decision unit, which are connected by at least four CPRI interfaces, at least one matching network and at least two dividers, the beam is modified and the modulated LTE signal is transmitted, **characterised in that**, by means of BBU, CSI-RS indicators are assigned to each one of at least 4 paths of the antenna modules (H1, H2), then these indicators are transmitted in DL channel to the UE and, by means of the UE, CQI value is determined based on the received CSI-RSs, the said CQI being, by means of the beam in the UL return channel, subsequently transmitted to all elements of the antenna, wherein an orthogonally polarised signal, included in the beam, is summed in the power divider (2), and, by means of CPRI interfaces, it is transmitted to BBU, and then this signal is demodulated by means of BBU, and based on CQI, by means of BBU, a path corresponding to the highest CQI which is optimal for the beam is chosen, and the modulated LTE signal, comprising PDSCH logical channel data is multiplied by controlling vectors [K] and [L] of a multiplier system in the RRH module, and then the signal is processed in a D/A converter, and then the signal is forwarded to an amplifier (3), where it is amplified, and further transmitted to the power divider (2), and subsequently to the radiators (1) of one polarisation.

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11. The method according to claim 10, **characterised in that** the beam in DL and UL direction is transmitted with the use of the radiators (1) having polarisations of +45° and -45°.

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12. The method according to claim 11, **characterised in that** dipoles are used as the radiators (1).

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13. The method according to claim 10, **characterised in that** for the internal sector of the cell, PDSCH 1 logical channel is used, and for the external sector of the cell, PDSCH 2 channel is used.

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14. The method according to any one of the preceding claims 10-13, **characterised in that** power dividers 1:2 or 1:3, or 1:4 are used as the power dividers (2).

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15. The method according to any one of the preceding claims 10-14, **characterised in that** by means of SON located in BBU, controlling vectors [K] and [L] are dynamically controlled.

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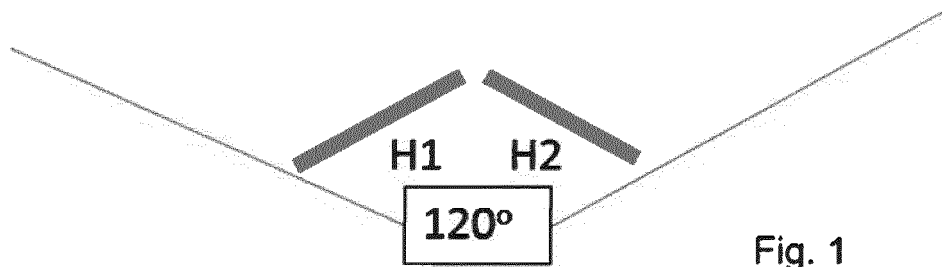


Fig. 1

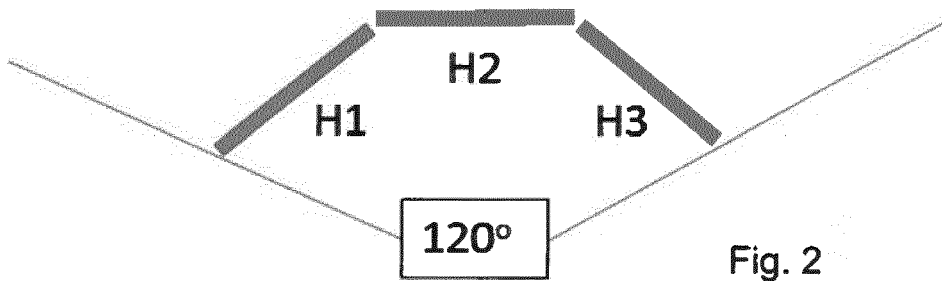


Fig. 2

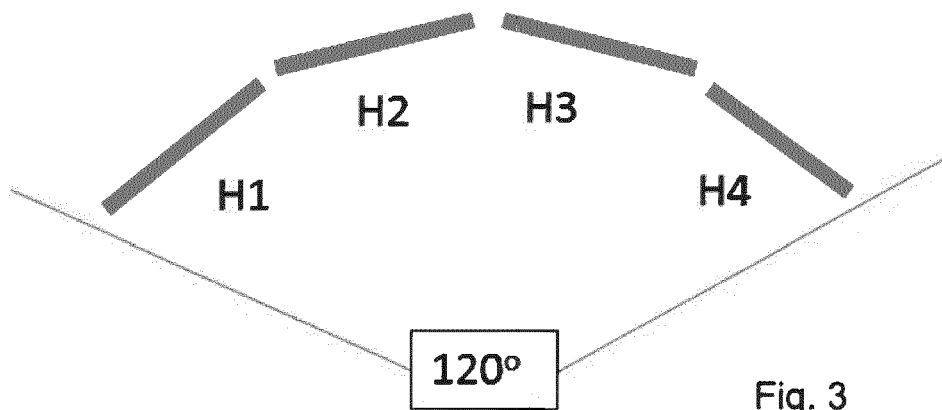
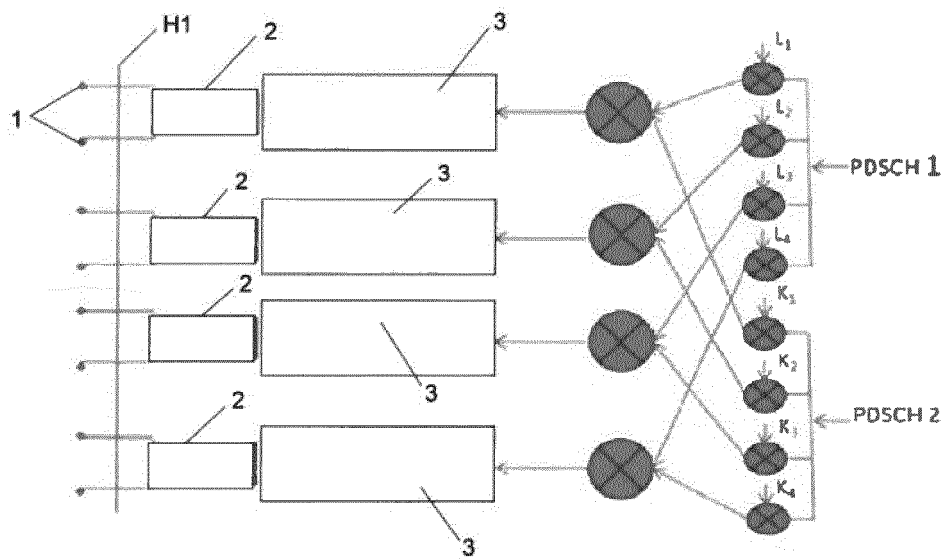
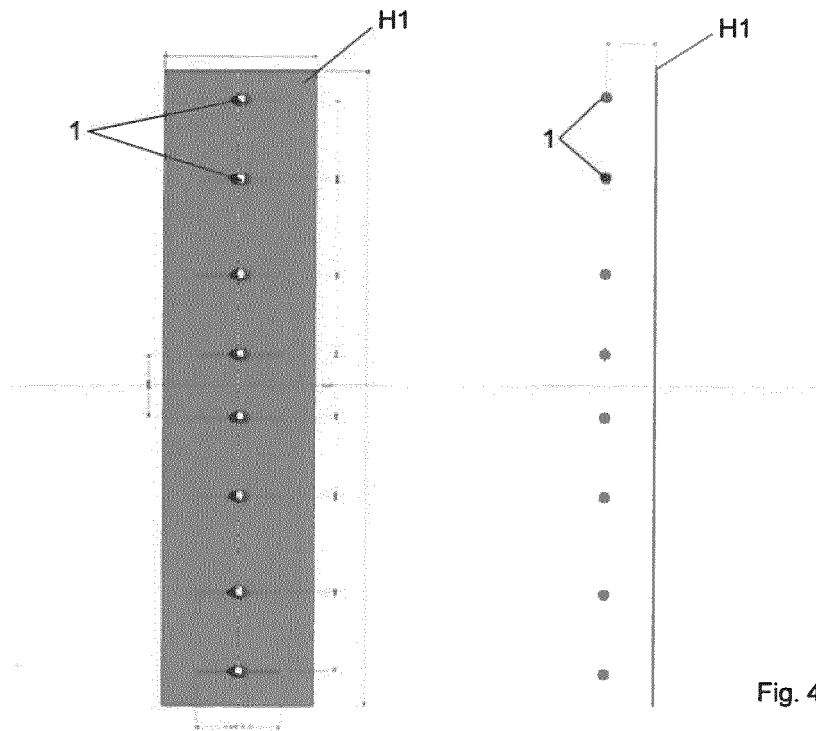


Fig. 3



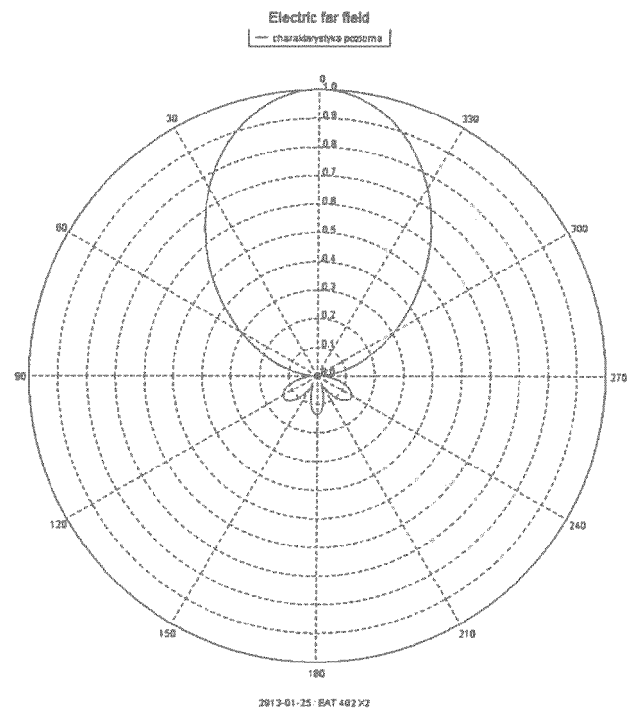


Fig.6

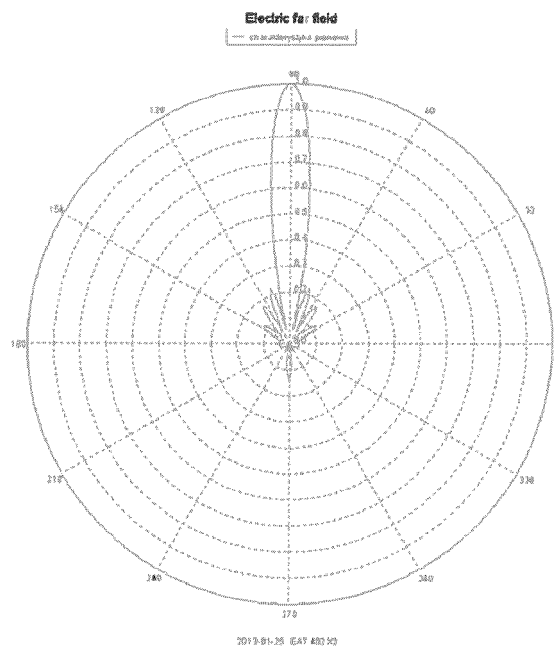


Fig.7

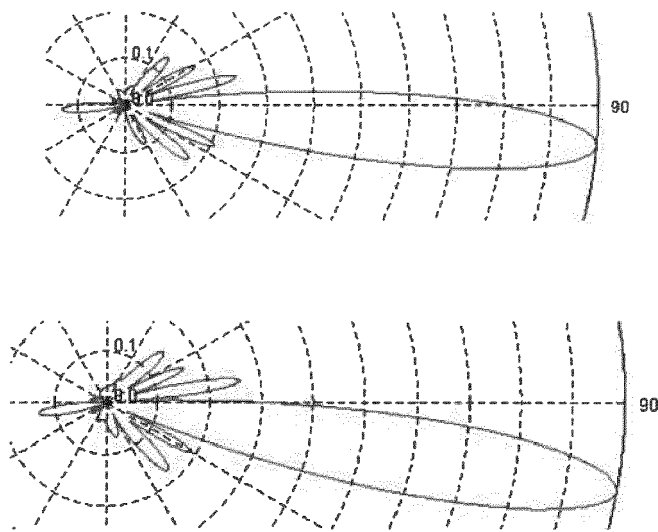


Fig.8

REFERENCES CITED IN THE DESCRIPTION

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