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(54) Interference reduction in cellular base station

(57) The disclosure relates to a system comprising an antenna (ANT) divided in two symmetric parts. Each part comprises a respective radiation element (RE_1, RE_2). The system is arranged to feed a first signal into a first radiation element (RE_1) of a first part of the antenna (ANT), to generate a second signal, and to feed the second signal into a second radiation element (RE_2) of the second part of the antenna (ANT). The second signal is obtained by substantially inverting the phase of the first signal.

The disclosure also relates to a cellular base station comprising such system, to a network of cellular base stations, to methods for reducing interferences, to a computer program for implementing such method, and to a storage medium storing such computer program.

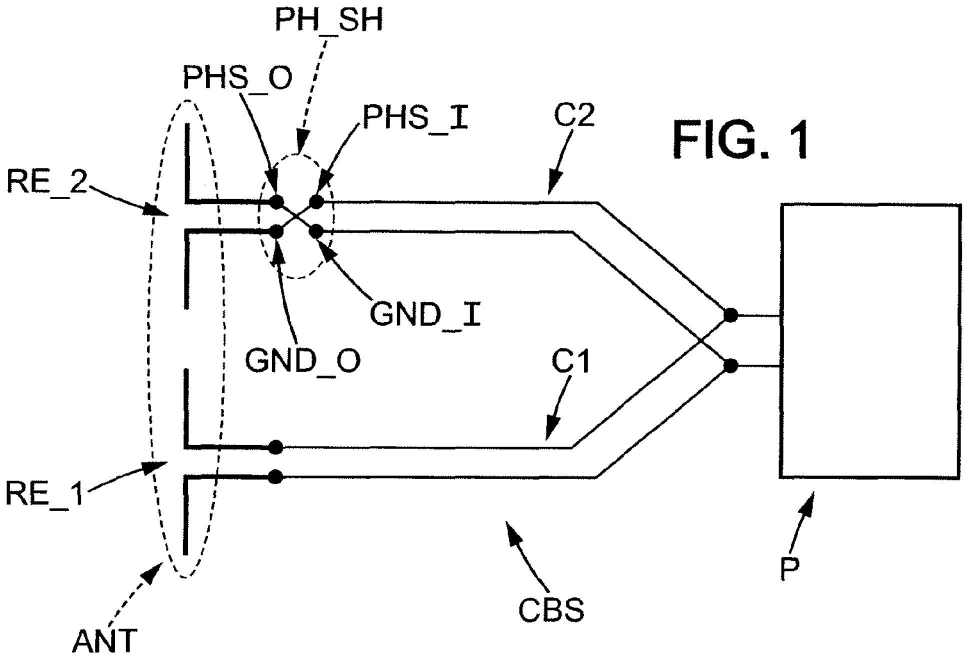

FIG. 1

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Description

[0001] The disclosure generally relates to cellular base stations and interferences generated by a cellular base station on neighboring cellular base stations.

[0002] Cellular base stations often comprise vertical radiation elements generating maximal radiations in the direction of the radio horizon (horizontally). However, cellular base stations are often located above the radio devices that they serve (e.g. at the top of a high building, or at the top of a mountain). This means that in a conventional system, no radio device is located at the altitude where the radiations are maximal, which is a waste of resources. Further, the radio horizon typically corresponds to neighboring cellular base stations (if such other stations are at a similar altitude). Therefore, the radio resources that are wasted for the radio device served by the cellular base station at stake are at the same time maximizing the level of interference with neighboring cells.

[0003] In order to resolve this problem, several techniques were proposed and implemented. A simple technique consists in tilting the radiation elements of the antenna of the cellular base station. Instead of being vertical, such radio elements are therefore slightly oriented towards the ground, which typically both reduces the level of interferences generated for neighboring cells and maximizes the signal available to the radio devices served by the cellular base station. However, this reduces the coverage area of the cell served by the cellular base station.

[0004] More specifically, a Bell Labs patent (US4249181) describes a cellular radiotelephone system with improved resistance to adjacent cells interferences, which is obtained by increasing an antenna tilt angle (antenna beam points below the horizon). But constant downtilt yields limited improvement of the electromagnetic compatibility properties.

[0005] An Ericsson patent (US6104936) discloses a technique for adapting the tilt angle for each base station antenna. An optimal antenna tilt angle is determined based in particular on an interference measurement. Each antenna can then be electro-mechanically tilted. However, using electrically controlled downtilt, while more effective than constant downtilt, still has a limited efficiency and substantially increases the cost of the cellular base station.

[0006] Cellular base stations are equipped with antennas, having a certain bandwidth. The bandwidth corresponds to a frequency interval in which the antenna has good performances (i.e. good parameters such as gain, radiation patterns, or VSWR). An antenna is designed in such a way that the bandwidth of signals to be sent or received be contained in its bandwidth (for example a GSM antenna is typically designed so as to cover all channels of the GSM system).

[0007] From an interference level standpoint, an important parameter is the vertical radiation pattern (VRP) of the antenna of the cellular base station. The VRP is representative of the relative amplitude level of the carrier, i.e. of the signal radiated by the antenna (in terms of electric field strength) as a function of the elevation angle, at an infinite distance (the VRP is distance independent). The VRP is in fact a vertical cross-section of the radiation pattern.

[0008] Relative interference levels are often assessed by computing a carrier to interference ratio, denoted C/I. Current base stations antennas typically comprise panels, each panel including a set of radiators placed on a vertical line one above another, or if the antenna is tilted, placed on a line which is not vertical but has a slope corresponding to the tilt angle. The bandwidth of the antennas being centered on a given frequency F, the centers of the radiators are separated by a distance equal to approximately lambda/2, with lambda equal to c/F (c being the speed of light). The radiators each have a screen in the backward direction, the screens having at least one plane of symmetry. The vertical axis of the dipoles belongs to a plane of symmetry of the screens. This plane of symmetry is the one in which the dipole can be tilted. When a tilt is applied, the whole panel is tilted (the panel is a single construction with all elements fixed with respect one to the other) in case of a mechanical tilt. In case of an electrical tilt, the feeding arrangement of the radiation elements of the panel is modified, without any mechanical changes of geometry. Currently used base station antennas may typically be considered as a set of elementary sources having identical parameters. Such elementary source containing one dipole and a screen (or portion of a screen) is also called a "patch" or "bay".

[0009] According to a simplified model (called synthetic model) the electric field strength E radiated at a given point (called the point of investigation, POI) for such panel is as follow:

$$E(\varphi,\theta)=\sum_{n}\frac{\sqrt{30P_nG_n(\varphi,\theta)}}{r_n}e^{j(\gamma_n+\frac{2\pi r_n}{\lambda})}$$

wherein:

r_n is the distance between the POI and the center of the n^{th} patch.

φ is the azimuth angle of the POI in a spherical coordinate system. The azimuth angle φ is defined as the angle between the projected vector and the reference azimuth vector. The projected vector is defined as the perpendicular projection of the POI azimuth vector onto a reference plane. The reference plane is any one of the planes perpendicular to the vertical axis of the dipoles. The azimuth origin is the intersection between the reference plane and the vertical axis of the dipoles. The POI azimuth vector is the vector which initial point is the azimuth origin and which terminal point is the POI. The reference azimuth vector is a vector which terminal point is the azimuth origin, which direction is parallel to the intersection of the reference plane and of a plane of symmetry of the screens of the antenna, the plane of symmetry being (in case there are many planes of symmetry) the one that includes the vertical axis of the dipoles. The initial point of the reference azimuth vector is any intersection of the screen with the line parallel to the reference azimuth vector and passing through the azimuth origin.

θ is the elevation angle of the POI. The elevation of a POI located on the vertical axis of the dipoles and above the elevation origin ("the sky") has an elevation of 0°. The elevation of a POI located on the vertical axis of the dipoles and below the elevation origin ("the ground") has an elevation of 180° (pi radians). The elevation of any POI which is not on the vertical axis of the dipoles is the positive angle (in the range of 0° to 180°) measured between the reference elevation vector and the POI elevation vector. The POI elevation vector is the vector which initial point is the elevation origin and which terminal point is the POI. The reference elevation vector is a vector which initial point is the elevation origin, and which terminal point is the highest point, located on the axis of the dipoles, of the top dipole. The elevation origin is the center of the segment which top end is the highest point of the highest dipole and which bottom end is the lowest point of the lowest dipole.

P_n is the average power (in Watts) delivered to the input of the n^{th} patch of the panel.

γ_n is the relative phase of the voltage delivered to the n^{th} patch.

$G_n(\varphi, \theta)$ is the gain of the n^{th} patch towards the POI relative to an isotropic antenna.

λ is the wavelength corresponding to the middle frequency F of the bandwidth of the antenna. For example, if the antenna is able to operate between Fmin = 550MHz and Fmax 650MHz, the middle frequency F is (Fmin+Fmax)/2 = 600MHz, and λ is equal to c/F = 50 centimeters.

[0010] In the synthetic model, the effects of the screen are ignored (as if there was no screen).

[0011] The synthetic model defines a radiation pattern. One can use the synthetic model in order to compute C/I. C is equal to the electric field strength at a given POI, emitted by a given antenna (composed of n patches), that is:

$$E(\varphi,\theta)=\sum_n \frac{\sqrt{30 P_n G_n(\varphi,\theta)}}{r_n} e^{j(\gamma_n+\frac{2\pi r_n}{\lambda})},$$

and I is equal to the sum of all electric field strengths, measured at the same given POI, that are emitted by all electromagnetic sources except the given antenna (in particular by all similar antennas of neighboring cells).

[0012] The invention seeks to improve the situation.

[0013] One aspect of the invention relates to a system comprising an antenna. The antenna is divided in two symmetric parts. Each part comprises a respective radiation element. The system is arranged to feed a first signal into a first radiation element of a first part of the antenna. The system is arranged to generate a second signal, and to feed the second signal into a second radiation element of the second part of the antenna. The second signal is obtained by substantially inverting the phase of the first signal.

[0014] Another aspect of the invention relates to a system comprising an antenna. The system is divided in two symmetric parts. Each part comprises a respective radiation element. The system is arranged to receive a first signal into a first radiation element of a first part of the antenna. The system is arranged to receive a second signal into a second radiation element of the second part of the antenna. The system is arranged to substantially invert the phase of the second signal.

[0015] Such systems are advantageous in that they provide better carrier to interference ratio C/I than may be achieved by the mechanical or electrical downtilt or simply by the propagation attenuation. The improvement of the C/I is due in particular to the reduction of the radiation towards the radio horizon. The invention enable splitting the antenna main beam into two beams (one useless beam towards the sky and a useful beam towards the ground), with no radiation in horizontal direction (towards potential co-channel base stations). In case the system is embedded in a cellular base station, this reduces interferences for neighboring cells (and removes interferences in the direction of the horizon), in particular co-channel interferences which affect adjacent cells in state of the art systems. Such cellular base station is also advantageous in that it improves the level of the useful signal in the service area of the cell.

[0016] Such cellular base station enables higher network capacity, spectrum savings, and lower license and operation costs. It is particularly advantageous when smaller cells with higher throughputs are planned and higher frequencies are used.

[0017] Another aspect of the invention relates to a cellular base station comprising a system according to embodiments of the invention.

[0018] Another aspect of the invention relates to a cellular network comprising cellular base stations according to embodiments of the invention.

[0019] The cellular network is advantageous in that its cell minimizes the interferences between the cellular base stations. In such network, each cellular base station not only reduces the level of interferences it generates for neighboring cellular base stations but also benefits from the reduced interferences generated by neighboring cellular base stations when such cellular base station are implemented according to embodiments of the invention.

[0020] Another aspect of the invention relates to a method for reducing interferences in a system comprising an antenna divided in two symmetric parts, each part comprising a respective radiation element. The method comprises:

/a/ feeding a first signal into a first radiation element of a first part of the antenna,

/b/ generating a second signal, and feeding the second signal into a second radiation element of the second part of the antenna,

the second signal being obtained by substantially inverting the phase of the first signal.

[0021] Another aspect of the invention relates to a method for reducing interferences in a system comprising an antenna divided in two symmetric parts, each part comprising a respective radiation element. The method comprises:

/a/ receiving a first signal from a first radiation element of a first part of the antenna,

/b/ receiving a second signal from a second radiation element of the second part of the antenna,

/c/ substantially inverting the phase of the second signal.

[0022] Another aspect of the invention relates to a computer program comprising one or more stored sequences of instructions that are accessible to a processor and which, when executed by the processor, cause the processor to carry out a method according to embodiments of the invention.

[0023] Another aspect of the invention relates to a non-transitory computer-readable storage medium storing a computer program according to embodiments of the invention.

[0024] Other aspects and advantages of the invention will become apparent from the following detailed description of specific embodiments of the invention, and the accompanying drawings, in which:

- Figure I represents a cellular base station according to a possible embodiment of the invention,
- Figure 2 represents a cellular base station according to a possible embodiment of the invention in which the phase shifter is a balun,
- Figure 3 represents a cellular base station according to a possible embodiment of the invention in which the phase shifter is a pair of cable which length is lambda/2 and which is integrally formed with the second connection,
- Figure 4 represents a cellular base station according to a possible embodiment of the invention in which the phase shifter is a pair of crossover cables which is integrally formed with the second connection,
- Figure 5 represents the VRP of an antenna according to a possible embodiment of the invention compared to the VRP of two known antennas, the VRP being plotted as a function of an elevation angle,
- Figure 6 represents the VRP of an antenna according to a possible embodiment of the invention, with two radiation elements, located at an altitude of 10m above the ground, compared to the VRP of two known antennas, the VRP being plotted as a function of a distance from the antenna,
- Figure 7 represents the VRP of an antenna according to a possible embodiment of the invention, with four radiation elements, located at an altitude of 25m above the ground, compared to the VRP of two known antennas, the VRP being plotted as a function of a distance from the antenna,
- Figure 8 represents the VRP of an antenna according to a possible embodiment of the invention, with eight radiation elements, located at an altitude of 35m above the ground, compared to the VRP of two known antennas, the VRP

being plotted as a function of a distance from the antenna,

- Figure 9 represents the VRP of an antenna according to a possible embodiment of the invention, with twelve radiation elements, located at an altitude of 50m above the ground, compared to the VRP of two known antennas, the VRP being plotted as a function of a distance from the antenna,

- Figure 10 represents the VRP of an antenna according to a possible embodiment of the invention, with twelve radiation elements, located at an altitude of 100m above the ground, compared to the VRP of two known antennas, the VRP being plotted as a function of a distance from the antenna, and

- Figure 11 represents a symbolic comparison between the beams of the three types of antennas shown on figures 5 to 10.

[0025] According to a first embodiment, a cellular base station CBS comprises an antenna ANT. The antenna is set to operate in a bandwidth centered on a given frequency F. Any antenna is set to operate in a given bandwidth [Fmin, Fmax]. The bandwidth is typically linked to the physical properties of the antenna. For example, the radiation element (s) of an antenna typically have a length which is of the same order of magnitude as the wavelength of the signals it is able to receive or transmit. F may be defined as (Fmin+Fmax)/2, typical values being for example F=900MHz (such as GSM 900), or F=1800MHz (such as DCS 1800). In general, Fmin and Fmax are close one to the other, i.e. Fmax/Fmin is close to the value 1. It is typically possible to have Fmax=F*1,1 and Fmin = F*0,9. In a possible example comprising a particular implementation of DCS 1800, the cellular base station is set to operate between 1710MHz and 1785 MHz for sending data and between 1805 MHz and 1880 MHz for receiving data. The antenna may accordingly be able to transmit signals with a certain level of quality between 1680 MHz and 1910 MHz, in which case F = (1680+1910)/2 = 1795MHz. The bandwidth is defined for a certain quality, for example for a quality corresponding to a signal loss of no more than a certain number of decibels (e.g. 3dB). Accepting a lower quality may only increase the corresponding bandwidth (up to a certain point, after which the bandwidth cannot be increased since no viable transmission would be possible anymore), while requiring a higher quality may only decrease the bandwidth. Modifying the quality level that is used to define the bandwidth generally does not affect substantially the value F, as it affects the upper and lower bounds of the bandwidth more or less symmetrically, and the mean F remains more or less constant.

[0026] The antenna comprises two radiation elements RE_1, RE_2 distributed vertically one above the other. The length of each radiation element is substantially equal to lambda/2 with lambda (the wavelength corresponding to frequency F) equal to c/F (c being the speed of light). Since Fmin and Fmax are generally of the same order of magnitude, the length of each radiation element is substantially equal to lambda/2 if it is equal to any value between c/(2*Fmax) and c/(2*Fmin).

[0027] The cellular base station further comprises a phase shifter PH_SH arranged to substantially invert the phase of a signal. Substantially inverting the phase of a signal corresponds to a phase difference of about 180° (i.e. pi radians) between the input signal and the signal output by the phase shifter. However, since the wavelengths of the signals processed by the antenna are not necessarily exactly lambda, the phase difference between the original signal and the signal output by the phase shifter may be slightly different, for example it may vary between 180°*(Fmin/F) and 180°*(Fmax/F). This is only an indication of the order of magnitude of the range of acceptable phase inversion. The phase inversion is typically somewhere between 170° and 190°, and a phase shifter can also add certain minor distortions to the signal while inverting its phase. The phase shifter may work both ways, i.e. it may have two input-outputs PH_SH_IO1 and PH_SH_IO2 such that any signal input into PH_SH_IO1 is output with substantially inverted phase at PH_SH_IO2, and conversely any signal input into PH_SH_IO2 is output with substantially inverted phase at PH_SH_IO1. However, in possible embodiments, the phase shifter works in only one way.

[0028] One of the radiation elements (RE_1) is connected to a port P of the cellular base station through a first connection C 1. The port may be connected for example to a transceiver, or to a mere transmitter, or to a mere receiver. If the port is connected to a transceiver, the phase shifter works both ways. If the port is connected to a transmitter or to a receiver, the phase shifter may work in only one way. The transceiver, transmitter or receiver may be embedded in the cellular base station.

[0029] The other radiation element (RE_2) is connected to the port of the cellular base station through a second connection C2 and through the phase shifter. In a possible embodiment, the phase shifter and the second connection are connected in series, the phase shifter being first and the second connection being second. In another embodiment, the phase shifter and the second connection are connected in series, the phase shifter being second and the second connection being first.

[0030] The first and second connections (C1and C2) have substantially identical transmission properties. For example, the first and second connections may be metallic cables (e.g. copper wires) with substantially the same length. Two connections have substantially the same length if their lengths differ by a few percents of lambda (e.g. less than lambda/

10). The two connections may be made of different metals or differ in any respect (such as their diameter) as long as this does not affect substantially their transmission properties (based on electrical characteristics, impedance, phase shift introduced at one end of the cable when a signal is injected at the other end, etc.). But it is advantageous for the two connections to be as similar as they can be. For example, they may be chosen so as to share as many identical or close characteristics as possible among in particular the length, the exact composition of the cable such as type of metal or alloy used (if the connections rely on metallic cables), the diameter, the date of manufacture, the manufacturer, the sheath, the type of bonding at both ends of the connections, etc.

[0031] It is possible to specify that connection C2 has to be shorter than connection C1 by the length travelled by the signal in the phase shifter PH_SH, however such length is typically negligible. This is therefore only an optional optimization, and even with this optimization the connections C1 and C2 typically have substantially the same length.

[0032] It would be possible to embed part of connection C2 within the phase shifter PH_SH, in which case the length of connection C2 to be taken into account (when comparing the length of connection C1 and the length of connection C2) is the length outside the phase shifter plus the length inside the phase shifter. For example, using two connections C1 and C2 each of length L and a phase shifter comprising a pair of cables, each cable of the pair having a length of lambda/2, is equivalent to using a connection C1 of length L, a connection C2 of length L-delta outside the phase shifter PH_SH, and a phase shifter comprising a pair of cables, each cable of the pair having a length of delta+lambda/2, the length delta belonging to connection C2.

[0033] The second connection C2 can be split in two parts C2a and C2b, and the phase shifter PH_SH may be inserted between the parts C2a and C2b.

[0034] Radiation elements RE_1 and RE_2 are advantageously identical. In a possible embodiment, the distance between the centers of the two radiation elements (RE_1 and RE_2) is substantially equal to lambda/2. Since the radiation elements have a length of about lambda/2, this means that the radiation elements are almost in contact one with the other (but there must be a least a small space between them in order to avoid an undesired electric contact).

[0035] Radiation elements are advantageously associated with a screen as in prior art antennas.

[0036] According to a second embodiment, the phase shifter PH_SH of the cellular base station according to the first embodiment comprises of a pair of cables which length is substantially equal to lambda/2. Such phase shifter is advantageous as it is passive and very simple, and can work in both ways. Any signal which wavelength is substantially lambda injected at any end of the pair of cables is output at the other end of the pair of cables with a substantially inverted phase.

[0037] According to a third embodiment, the phase shifter PH_SH of the cellular base station according to the first embodiment comprises two input contacts (GND_I, corresponding to the ground signal, and PHS_I, corresponding to the hot signal) for receiving a signal and two associated output contacts (GND_O, corresponding to the ground signal, and PHS_O, corresponding to the hot signal). For example, the signal, relative to a ground signal, may be injected on PHS_I while GND_I is connected to the ground signal. The first input contact GND_I is shorted with the second output contact PHS_O and the second input contact PHS_I is shorted with the first output contact GND_O, thereby outputting the same signal but with inverted phase. Accordingly, this arrangement enables injecting a signal in the first radiation element RE_1 and the opposite signal in the second radiation element RE_2.

[0038] Such phase shifter is advantageous as it is passive and very simple, and can work in both ways. Indeed, the input-output PH_SH_IO1 of the phase shifter may comprise the input contacts GND_I and PHS_I while the input-output PH_SH_IO2 may comprise the input contacts GND_O and PHS_O. The input contacts GND_I and PHS_I may accordingly be used as output contacts when the output contacts GND_O and PHS_O are used as input contacts.

[0039] In addition, any signal, irrespective of its frequency (as long as its wavelength remains substantially greater than the elements forming the phase shifter), which is injected at any end of the pair of cables is output at the other end of the pair of cables with a substantially inverted phase.

[0040] Such phase shifter inverses the polarity of the signal and can be achieved with crossed cables. For example two cables linking GND_I and PHS_I to GND_O and PHS_O can be swapped over. The respective length of such two crossover cables must be small compared to lambda/2. Such length is advantageously as small as possible. The lengths of the two cables may be quite different as long as they are small, for example a first cable can have a length of lambda/20 and the second cable may have a length of lambda/40 (i.e. be twice shorter).

[0041] According to a fourth embodiment, the phase shifter PH_SH of the cellular base station according to the first embodiment comprises a balun, as illustrated on figure 2 (on this example the connection C2 is split in two sub-connections C2a and C2b).

[0042] It should be noted that there is typically a balun (or a functionally equivalent device based for example on a choke or on a ferrite core) at the interface between connection C 1 (respectively C2) and radiation element RE_1 (respectively RE_2). Indeed, connections C1 and C2 are typically based on coaxial cables which impedance is typically adapted to the dipoles (radiation elements RE_1 and RE_2) with the conventional balun. This conventional balun is not represented on the figures. Not using any such conventional balun (or equivalent device) is conceivable (it could be justified by the need to avoid signal losses that are introduced by a balun), but is likely to cause sheath currents which in turn result in undesired interferences.

[0043] Accordingly, the balun according to the fourth embodiment can be either a dedicated balun (used in addition to the conventional balun in case there is a conventional balun), or it can be merged with the conventional balun, i.e. the conventional balun can be modified so as to introduce a phase inversion for frequencies close to F.

[0044] According to a fifth embodiment, the phase shifter PH_SH and the second connection C2 of the cellular base station according to any of the first to fourth embodiments are integrally formed.

[0045] For example, as illustrated on figure 3, the first connection may be a pair of cables of length L, while the second connection and phase shifter are a pair of cables of length equal to L+lambda/2, or at least substantially equal. Substantially equal means that the difference between the length of two cables in one pair is small compared to lambda, and that the difference between the length of a cable of the pair corresponding to the second connection and the length equal to lambda/2 plus the length of a cable of the pair corresponding to the first connection is small compared to lambda (e.g. much less than lambda/10). In such case, there is advantageously no physical interface between the phase shifter and the second connection, but only a logical interface. The phase shifter and the second connection are then formed by a single pair of cables, and a logical interface may be viewed as two particular points, one on each of the two cables of the pair. The points are not necessarily distinguishable from other points of the cables, although in possible embodiments they may be marked (e.g. with markings on the sheaths, in a well noticeable color such as red on a black cable).

[0046] In another example, illustrated on figure 4, the first connection may be a pair of straight cables of length L, while the second connection and phase shifter are a pair of crossover cables of same (or substantially same) length L as the cables of the first connection. The four cables are said to have substantially the same length when the difference between the lengths of any two cables out of the four cables is small compared to lambda. In such example, there is advantageously no physical interface between the phase shifter and the second connection, but only a logical interface. At least one of the input-output (PH_SH_IO1 or PH_SH_IO2) of the phase shifter is a logical interface as in the previous example (i.e. mere points on the cables, which are not necessarily distinguishable from other points on the cable). On figure 4, both PH_SH_IO1 and PH_SH_IO2 are logical interfaces

[0047] According to a sixth embodiment, the antenna ANT of the cellular base station according to any of the first to fifth embodiments comprises an even number 2*N, with N strictly greater than 1, of radiation elements distributed vertically one above the other. The length of each radiation element is substantially equal to lambda/2. The cellular base station further comprises a number N of phase shifters, each phase shifter being arranged to substantially invert the phase of a signal. Half of the radiation elements are connected to the port P of the cellular base station through a first set of N connections. The other half of radiation elements is connected to the port P of the cellular base station through a second set of N connections and through a respective phase shifter. The connections of the first and second sets of connections have substantially identical transmission properties.

[0048] According to a seventh embodiment, the antenna ANT of the cellular base station according to any of the first to fifth embodiments comprises an even number 2*N, with N strictly greater than I, of radiation elements distributed vertically one above the other. The length of each radiation element is substantially equal to lambda/2. Half of the radiation elements are connected to the port P of the cellular base station through a first set of N connections. The other half of radiation elements is connected to the port P of the cellular base station through a second set of N connections and through the phase shifter PH_SH (which is shared with all N connections of the second set). The connections of the first and second sets of connections have substantially identical transmission properties.

[0049] The following may be applied to both the sixth and seventh embodiments.

[0050] In a possible embodiment, the distance between the centers of any two consecutive radiation elements is constant (for example substantially equal to lambda/2).

[0051] In a possible embodiment, the top N radiation elements are connected to a phase shifter while the bottom N radiation elements are not. In an alternative embodiment, the bottom N radiation elements are connected to a phase shifter while the top N radiation elements are not.

[0052] In a possible embodiment, which can be combined with the previous two embodiments, the antenna being divided in two parts, a top part containing the top N radiation elements and a bottom part containing the bottom N radiation elements, the two parts are symmetric, which means that the positions of the centers of the top N radiation elements are symmetric with respect to the positions of the centers of the bottom N radiation elements. More specifically, in a possible embodiment, the distance between the centers of any two consecutive radiation elements taken from the top N radiation elements is constant (for example substantially equal to lambda/2), the distance between the centers of any two consecutive radiation elements taken from the bottom N radiation elements is constant (for example substantially equal to lambda/2), and the distance between the center of the lowest radiation element of the top N radiation elements and the center of the highest radiation element of the bottom N radiation elements is substantially greater than lambda/2 (e.g. comprised between lambda/2 and lambda, or even greater than lambda), thereby providing higher co-channel interference rejection. Increasing the distance between the bottom half of the antenna (N lowest radiation elements) and the top half of the antenna is advantageous as it enables the modification of the "beam tilt", a drawback being that the height of the antenna is increased.

[0053] All radiation elements are advantageously associated with a screen as in prior art antennas.

[0054] The value N can take any value but the most relevant values are between N=1 and N=10 (for which there are 20 radiation elements). The more radiation elements, the higher the gain of the antenna. More radiation elements may affect the feeding arrangement (more bays may require null filling).

[0055] In a possible embodiment, any connection of the first set of connections has substantially identical transmission properties as any connection of the second set of connections. However, in general, it is sufficient for each connection of the first set of connections to have substantially identical transmission properties as the respective connection of the second set of connections (and not as all other connections of the second set, which may be different).

[0056] According to an eighth embodiment, a cellular network comprises cellular base stations according to any of the first to seventh embodiments.

[0057] A ninth embodiment relates to a method for reducing interferences caused by a cellular base station CBS on neighboring cellular base stations. The cellular base station CBS comprises an antenna set to operate in a bandwidth centered on a given frequency F. The antenna comprises two radiation elements (RE_1 and RE_2) distributed vertically one above the other. The length of each radiation element is substantially equal to lambda/2 with lambda equal to c/F. The method comprises:

/a/ feeding a signal from a port of the cellular base station into a first radiation element RE_1 through a first connection C 1, and

/b/ feeding the signal into a second radiation element RE_2 through a second connection C2 and through a phase shifter PH_SH, the phase shifter being arranged to substantially invert the phase of the signal that it processes.

[0058] The first and second connections have substantially identical transmission properties.

[0059] The signal of step /a/ can come from a transmitter or transceiver which may be embedded in the cellular base station and be connected to the port P, or may come from an external entity connected to the cellular base station.

[0060] In a possible embodiment, step /b/ can be decomposed in:

/b1/ obtaining a second signal by feeding the signal of step /a/ (signal obtained from port P) into the phase shifter,

/b2/ feeding the second signal into the second radiation element through the second connection.

[0061] In an other embodiment, step /b/ can be decomposed in:

/b1/ feeding the signal of step /a/ (signal obtained from port P) into the phase shifter, through the second connection,

/b2/ feeding the phase inverted signal (obtained in step /b1/) into the second radiation element. The feeding step /b2/ is carried out directly, e.g. with a very short cable (much shorter than lambda, e.g. of length smaller than lambda/ 10), or by connecting the phase shifter directly to the second radiation element (as illustrated on figure 1), in order to avoid any further substantial distortion or phase shift.

[0062] In an other embodiment, step /b/ can be decomposed in:

/b1/ feeding the signal of step /a/ (signal obtained from port P) into the phase shifter, through a subset C2a of the second connection C2,

/b2/ feeding the phase inverted signal (obtained in step /b1/) into the second radiation element through a subset C2b of the second connection C2.

[0063] The cellular base station may comprise 2*N radiation elements (with N greater than or equal to 1).

[0064] A tenth embodiment relates to a method for reducing interferences received by a cellular base station CBS from neighboring cellular base stations. This method is similar to the method according to the ninth embodiment except that it is applied to the reception of signals rather than to the transmission of signals. The cellular base station comprises an antenna ANT which is set to operate in a bandwidth centered on a given frequency F. The antenna comprises two radiation elements distributed vertically one above the other. The length of each radiation element (RE_1 and RE_2) is substantially equal to lambda/2 with lambda equal to c/F. The method comprises:

/a/ feeding a signal received from a first radiation element RE_1 into a port P of the cellular base station through a first connection C1, and

/b/ feeding a signal received from a second radiation element RE_2 into the port P of the cellular base station through a second connection C2 and through a phase shifter PH_SH, the phase shifter being arranged to substantially invert the phase of the signal it receives.

[0065] The first and second connections have substantially identical transmission properties.
[0066] The signal fed in port P during step /b/ can then be fed into a receiver or transceiver.
[0067] In a possible embodiment, step /b/ can be decomposed in:

/b1/ obtaining a second signal by feeding the signal of step /a/ (signal received from the second radiation element) into the phase shifter,

/b2/ feeding the second signal into port P through the second connection.

[0068] In an other embodiment, step /b/ can be decomposed in:

/b1/ feeding the signal of step /a/ (signal obtained from the second radiation element) into the phase shifter, through the second connection,

/b2/ feeding the phase inverted signal (obtained in step /b1/) into port P. The feeding step /b2/ is carried out directly, e.g. with a very short cable (much shorter than lambda, e.g. of length smaller than lambda/10), or by connecting the phase shifter directly to port P, in order to avoid any further substantial distortion or phase shift.

[0069] In an other embodiment, step /b/ can be decomposed in:

/b1/ feeding the signal of step /a/ (signal obtained from the second radiation element) into the phase shifter, through a subset C2b of the second connection C2,

/b2/ feeding the phase inverted signal (obtained in step /bt/) into port P through a subset C2a of the second connection C2.

[0070] When a signal from a cellular device is received through 2*N radiation elements of the cellular base station, the signals received from N radiation elements can have their phase inverted, the signals from the other N radiation elements can have their phase unchanged, and the 2*N resulting signals can be summed or averaged on port P, which can be connected to a receiver or transceiver.
[0071] A tenth embodiment relates to a computer program comprising one or more stored sequences of instructions that are accessible to a processor and which, when executed by the processor, cause the processor to carry out a method according to the ninth embodiment.
[0072] In particular, in a possible embodiment, the cellular base station comprises a processor which can trigger switches in order to decide which signals to subject to phase inversion and which to leave unchanged. For example, when the phase shifter is based on cables of length lambda/2, each lambda/2 long cable can be conformed as a loop, with both ends of the lambda/2 cable connected through a switch. When the switch is activated, the loop is shorted and the phase inversion disappears.
[0073] When the phase shifter is based on crossover cables, a switch can invert the two contacts of the output in order to come back to a straight cables situation.
[0074] When the phase shifter is based on dedicated balun, a switch can short the contacts normally connected via the dedicated balun, and optionally disconnect the dedicated balun from such contacts, in order to cancel the phase inversion effect of the dedicated balun.
[0075] The program may comprise functions taking as input parameters one or more switch control parameter(s), and optionally an identifier (or a series of identifiers). The identifier(s) may comprise a switch identifier (e.g. an integer s between 1 and the maximum number of switches that can serve a radiation element), a radiation element identifier (such as an integer k between 1 and 2*N), a panel identifier (e.g. in case there are several panels per antenna), and an antenna identifier (in case there are several antennas in the cellular base station). There could even be a cellular base station identifier.
[0076] Many different kinds of identifiers are possible. For example, it is possible to use a unique switch identifier on a cellular station basis (e.g. a 16 bit value), or even on a cellular network operator basis. Accordingly, it is not necessary to identify the radiation element, the panel and the antenna.
[0077] Alternatively, it is possible to not identify the switch explicitly but only implicitly, for example by identifying a particular radiation element, and by sending, as a switch control parameter, a vector (or a list, or simply a series of elements) which size (number of elements) corresponds to the maximum number of switches that can serve a radiation

element, each element of the vector corresponding to a respective switch and containing the respective switch control parameter.

[0078] The switch control parameters can be Boolean ON/OFF parameters. Alternatively, they may be a ternary-value parameter such as ON/OFF/STAY (according to which the switch is activated, deactivated, or remains in the previous state).

[0079] However, according to possible embodiments, a cellular base station comprises no software for carrying out the method according to embodiments of the invention (but of course it can, and typically does, comprise software for carrying out other tasks), and/or comprises no switch for connecting or disconnecting the phase shifter(s) PH_SH. Such embodiments are advantageous in that, although less flexible, they are simpler (and accordingly cheaper to manufacture), and typically more reliable (as less elements are likely to fail or to be subject to software bugs).

[0080] An eleventh embodiment relates to a non-transitory computer-readable storage medium storing a computer program according to the tenth embodiment.

[0081] Figures 5 to 10 represent the VRP of various types of antennas in different situations. The VRPs are plotted on the basis of the synthetic model.

[0082] In all six figures, the curves in dotted lines represent the VRP for a state of the art antenna, without any downtilt. The curves in segmented lines represent the VRP for a state of the art antenna, in which a mechanical or electrical downtilt is applied. The curves in solid lines represent the VRP for an antenna of a cellular base station according to an embodiment of the invention.

[0083] In all six figures, the VRP is normalized to 1.

[0084] The origin of the spherical coordinate system used to plot figures 5 to 10 is defined as the center of the segment which top end is the highest point of the highest radiation element of the antenna according to the embodiment of the invention concerned, and which bottom end is the lowest point of the lowest radiation element of the antenna according to the embodiment of the invention concerned.

[0085] In figures 5 to 10, the VRP is expressed as a function of the elevation angle, and is plotted for an azimuth angle of zero degree (the azimuth angle is relevant only to the segmented curve in which the antenna is tilted, for other curves the azimuth is not a relevant parameter since the screen is ignored in the synthetic model).

[0086] Figures 6 to 10 use a scale different from the scale of figure 5. While the vertical scale for the VRP is linear for figure 5, it is logarithmic for figures 6 to 10. In figures 6 to 10, the VRP is expressed not only as a function of the elevation angle, but also as a function of a specific distance equivalent to this elevation angle. The distance information and elevation angle information are therefore redundant, but the distance information is chosen so as to be easier (more intuitive) to assess when analyzing the figures. While the horizontal scale for the elevation angle is linear for figure 5, the horizontal scale is logarithmic for figures 6 to 10 with respect to the equivalent distance that is used for the horizontal scale. A conventional user of a cellular device is assumed to hold the cellular device at an altitude of 1.5m above ground level. Accordingly, figures 6 to 10 consider, for each elevation angle, the point located at said elevation angle, at an azimuth of zero, and at an altitude of 1.5m above ground level. This point is at a certain horizontal distance from the vertical axis going through the origin. This horizontal distance is the one that is used on the horizontal axis of figures 6 to 10.

[0087] Figures 6 to 10 take into account free space attenuation while figure 5 does not.

[0088] Figure 5 is plotted for a cellular base station according to a first embodiment of the invention, having two vertical radiation elements which length is lambda/2 and which are one above the other (their centers are located at a distance lambda/2 one of the other). It is assumed that there is a distance epsilon (almost zero) between the two radiation elements so that they are not in short circuit (i.e. the distance between their centers is in fact epsilon+lambda/2 with epsilon being negligible). The other two antennas for which the VRPs are plotted are the same except that the one corresponding to the segmented curve is tilted with a downtilt angle of 18.8°.

[0089] The amplitude of the excitation applied to both dipoles (both radiation elements) is equal but the phase of the excitation applied to one dipole is opposite to the one applied to the other dipole for the solid curve (about 180° difference according to the invention) while the phases are equal for the two other curves.

[0090] Figure 5 shows that the VRP for the antenna according to this embodiment (VRP in solid line) present no radiation in the direction of the radio horizon (i.e. elevation angle of 90°, which corresponds to a line parallel to the ground).

[0091] The dotted curve shows a maximum radiation in the direction of the radio horizon. This corresponds to the regular antenna without downtilt, which has the highest gain and the highest coverage area (but also the highest coverage in terms of interferences for neighboring cells).

[0092] The segmented curve shows a certain level of attenuation of the radiation in the direction of the radio horizon, but not as good as with this embodiment of the invention (it is not zero).

[0093] Figure 6 is plotted with the same hypothesis as figure 5, except that it takes into account free space attenuation. In figure 6, the origin of the spherical coordinate system is located ten meters above the ground. The distance shown on the horizontal axis is computed on this basis.

[0094] The parameters used for figure 6 can be used for example for a femto cell. Femto cell antennas are typically mounted indoors, under the ceiling, and have a typical range of approximately 50m to 150m. Figure 6 shows that at a distance greater than 30m from the antenna, the attenuation starts being much stronger (i.e. the generated interference is much lower) with the embodiment according to the invention than with state of the art solutions.

[0095] Figure 7 is similar to figure 6 except that the three antennas each have four bays (for radiation elements). As in figures 5 and 6, each radiation element is vertical when not tilted, and only the radiation elements of the segmented curve are tilted (downtilt of 18.8°, which is a typical value, but other values can be used). When not tilted, the radiation elements are all aligned in a vertical line one above the other (as in figures 5 and 6). As in figures 5 and 6, each radiation element has a length of lambda/2 and the centers of two consecutive radiation elements are distant of epsilon+lambda/2, with epsilon negligible compared to lambda/2. Contrary to figures 5 and 6, the antenna (i.e. the origin of the spherical coordinate system) is located 25 meters above the ground (the altitude was irrelevant in figure 5 and was equal to 10 meters in figure 6).

[0096] Figure 7 shows that for distance greater than about 300 meters, the interferences generated by this embodiment of the invention are much lower than prior art for neighboring cells, which is particularly advantageous for example for pico cells.

[0097] Figure 8 is similar to figure 7 except that the three antennas each have eight bays (instead of four) and that the origin of the spherical coordinate system (i.e. the center of the three antennas) is located 35 meters above the ground, instead of 25 meters.

[0098] Figure 8 shows that for distance greater than about 1000 meters, the interferences generated by this embodiment of the invention are much lower than prior art for neighboring cells, which is particularly advantageous for example for micro cells.

[0099] Figure 9 is similar to figure 8 except that the three antennas each have twelve bays (instead of eight) and that the origin of the spherical coordinate system (i.e. the center of the three antennas) is located 50 meters above the ground, instead of 35 meters.

[0100] Figure 9 shows that for distance greater than about 1500 meters, the interferences generated by this embodiment of the invention are much lower than prior art for neighboring cells, which is particularly advantageous for example for typical mobile telephony cells.

[0101] Figure 10 is similar to figure 9 except that the origin of the spherical coordinate system (i.e. the center of the three antennas) is located 100 meters above the ground, instead of 50 meters.

[0102] Figure 10 shows that for distance greater than about 2000 meters, the interferences generated by this embodiment of the invention are much lower than prior art for neighboring cells, which is particularly advantageous for example for macro cells.

[0103] The distances (30m, 300m, 1000m, 1500m and 2000m) indicated for each of figure 6 to figure 10, such that the interferences generated are much lower at such distances, are purely illustrative (the interference reduction is also better at lower distances, and is even better at higher distances). What matters is that the additional signal attenuation brought by the cellular base station according to various embodiments of the invention illustrated on figures 6 to 10 becomes substantial starting from a certain distance, and this distance can be chosen by choosing the number of radiation elements of the antenna and of the altitude of the antenna. The distance grows when the number of radiation elements grows, and when the altitude grows. Accordingly, the useful signal is present in the defined coverage area (based on the selected distance), and beyond this distance the signal level is substantially lower, thereby reducing interferences for other cells. However the base cellular base station according to the above embodiments has a reduced coverage area compared to state of the art solutions.

[0104] Figure 11 illustrates symbolically the beams of the three types of antennas which VRP is shown on figures 5 to 10.

[0105] A non-tilted state of the art antenna has a horizontal beam which is very sensitive to interference from neighboring cells. It is maximally sensitive to interferences from cells which antennas are at the same altitude.

[0106] A state of the art antenna tilted in a known manner has a tilted beam which is not as tilted as the one according to possible embodiments of the invention, and which remains quite sensitive to interferences from neighboring cells.

[0107] The antenna of a cellular base station according to possible embodiments of the invention splits the radiation beam into two beams (the highest one and the lowest one on figure 11). The highest beam is not used. But the beam that is directed towards the ground generates low interference level for other cells, especially with the co-channel cells, and is adapted to better manage interferences from co-channel cells. There is no interference in the direction of the horizon. The tilting of the beam is not only higher, but also different from known beam tilting (which is based on antenna tilting).

[0108] The above embodiments are illustrative only and are not intended to limit the scope of the invention. In particular, the above embodiments relate to cellular base stations, without limitation. The cellular base station can be a GSM base station, a 3GPP eNodeB, etc.

[0109] A cellular base station can comprise different antennas, e.g. a 900MHz GSM antenna as well as a 1800MHz DCS antenna, and any number of antennas out of all antennas of the cellular base station can be implemented in accordance with the above embodiments of the invention. Metallic cable based connections C1 and C2 (jumper/feeder cables) have been disclosed, however where appropriate other types of connections can be used as well (e.g. optical fibers with optical/electrical transceivers and power amplifiers).

[0110] From the antenna standpoint the exact nature of the signal is irrelevant. The signal can be properly sent or receive as long as its spectrum is contained within the antenna bandwidth, whether it is digital or analog signal, and irrespective of the type of modulation that is used (CDMA, OFDM), etc. Therefore the invention is not limited to a particular signal nature (digital or analog, and for any type of modulation), and may work for example with any frequency, for example frequencies above 300 MHz, such as CDMA450, GSM900, UMTS2100, LTE800 etc.

[0111] The embodiments describing possible cellular base stations according to the invention are applicable to the cellular network embodiments, to the method embodiments, to the computer program embodiments and to the storage medium embodiments, and vice versa.

[0112] In certain embodiments, the radiation elements are disposed on a vertical line, and this is appropriate for a vertical polarization. However, the radiation elements do not have to be disposed on a vertical line, as long as they are distributed vertically one above the other (i.e. the centers of the radiation elements are on a vertical line), which can be useful for example for +45°/-45° polarizations. In addition, it is possible to combine the various embodiments of the invention with a mechanical or electrical tilt of the antenna (i.e. the antenna of the cellular station can be mechanically and/or electrically tilted).

Claims

1. A system comprising an antenna (ANT) divided in two symmetric parts, each part comprising a respective radiation element (RE_1, RE_2), the system being arranged to feed a first signal into a first radiation element (RE_1) of a first part of the antenna (ANT), to generate a second signal, and to feed the second signal into a second radiation element (RE_2) of the second part of the antenna (ANT), the second signal being obtained by substantially inverting the phase of the first signal.

2. The system according to claim 1, wherein the antenna (ANT) is set to operate in a bandwidth centered on a given frequency F, the length of each radiation element (RE_1, RE_2) being substantially equal to lambda/2 with lambda equal to c/F.

3. The system according to claim 1, wherein each of the two symmetric parts comprises a plurality of radiation elements.

4. The system according to claim 1, wherein the two radiation elements (RE_1, RE_2) are distributed vertically one above the other, the system further comprising a phase shifter (PH_SH) arranged to substantially invert the phase of a signal, one of the radiation elements (RE_1) being connected to a port (P) of the system through a first connection (Cl), the other radiation element (RE_2) being connected to the port (P) of the system through a second connection (C2) and through the phase shifter (PH_SH), the first and second connections (C1, C2) having substantially identical transmission properties.

5. The system according to claim 4, wherein the phase shifter (PH_SH) comprises of a pair of cables which length is substantially equal to lambda/2.

6. The system according to claim 4, wherein the phase shifter (PH_SH) comprises of a device comprising two input contacts (GND_I, PHS_I) for receiving a signal and two associated output contacts (GND_O, PHS_O), wherein the first input contact (GND_I) is shorted with the second output contact (PHS_O) and the second input contact (PHS_I) is shorted with the first output contact (GND_O), thereby outputting the same signal but with inverted phase.

7. The system according to claim 4, wherein the phase shifter (PH_SH) comprises a balun.

8. The system according to claim 4, wherein the phase shifter (PH_SH) and the second connection (C2) are integrally formed.

9. The system according to claim 4, wherein the antenna (ANT) comprises an even number 2*N, with N strictly greater than 1, of radiation elements distributed vertically one above the other, the length of each radiation element being substantially equal to lambda/2, the system further comprising a number N of phase shifters, each phase shifter being arranged to substantially invert the phase of a signal, half of the radiation elements being connected to the port (P) of the system through a first set of N connections, the other half of radiation elements being connected to the port (P) of the system through a second set of N connections and through a respective phase shifter, the connections of the first and second sets of connections having substantially identical transmission properties.

10. The system according to claim 4, wherein the antenna (ANT) comprises an even number 2*N, with N strictly greater than I, of radiation elements distributed vertically one above the other, the length of each radiation element being substantially equal to lambda/2, half of the radiation elements being connected to the port (P) of the system through a first set of N connections, the other half of radiation elements being connected to the port (P) of the system through a second set of N connections and through the phase shifter (PH_SH), the connections of the first and second sets of connections having substantially identical transmission properties.

11. A system comprising an antenna (ANT) divided in two symmetric parts, each part comprising a respective radiation element (RE_1, RE_2), the system being arranged to receive a first signal into a first radiation element (RE_1) of a first part of the antenna (ANT), to receive a second signal into a second radiation element (RE_2) of the second part of the antenna (ANT), and to substantially invert the phase of the second signal.

12. A cellular base station (CBS) comprising a system according to claim 1.

13. A cellular network comprising cellular base stations (CBS) according to claim 11.

14. A method for reducing interferences in a system comprising an antenna (ANT) divided in two symmetric parts, each part comprising a respective radiation element (RE_1, RE_2), wherein the method comprises:

/a/ feeding a first signal into a first radiation element (RE_1) of a first part of the antenna (ANT),
/b/ generating a second signal, and feeding the second signal into a second radiation element (RE_2) of the second part of the antenna (ANT),
the second signal being obtained by substantially inverting the phase of the first signal.

15. A method for reducing interferences in a system comprising an antenna (ANT) divided in two symmetric parts, each part comprising a respective radiation element (RE_1, RE_2), wherein the method comprises:

/a/ receiving a first signal from a first radiation element (RE_1) of a first part of the antenna (ANT),
/b/ receiving a second signal from a second radiation element (RE_2) of the second part of the antenna (ANT),
/c/ substantially inverting the phase of the second signal.

16. A computer program comprising one or more stored sequences of instructions that are accessible to a processor and which, when executed by the processor, cause the processor to carry out a method according to claim 14 or 15.

17. A non-transitory computer-readable storage medium storing a computer program according to claim 16.

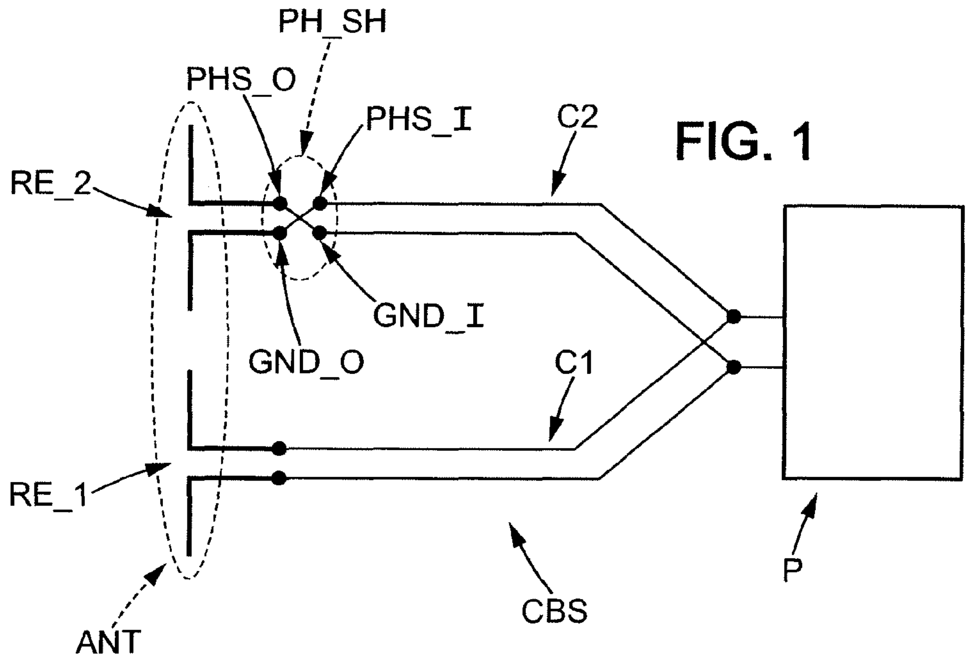
PH_SH
PHS_O
PHS_I
C2
RE_2
GND_I
GND_O
C1
RE_1
P
CBS
ANT

FIG. 1

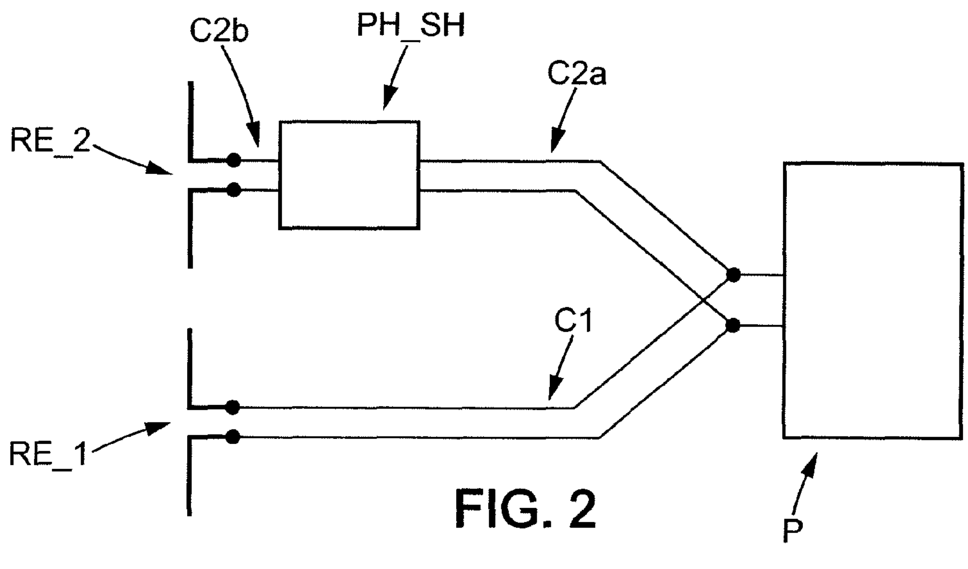
C2b
PH_SH
C2a
RE_2
C1
RE_1
P

FIG. 2

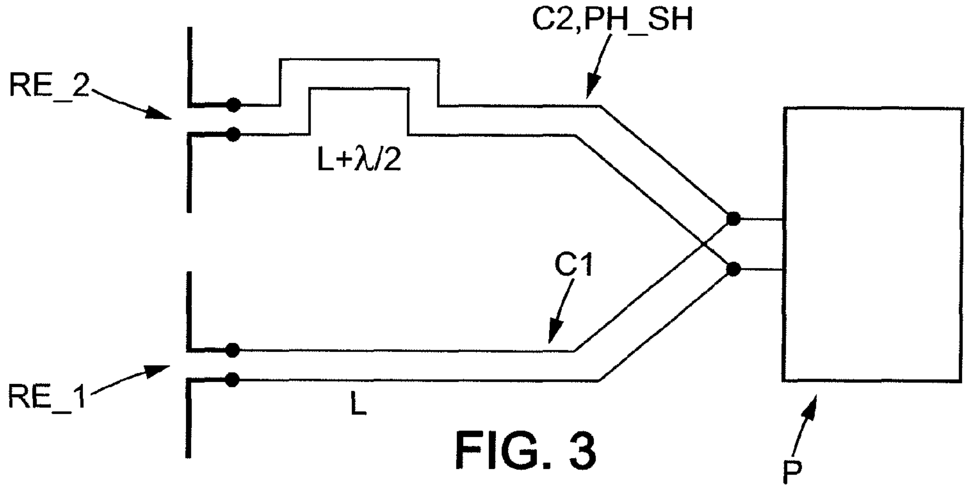

FIG. 3

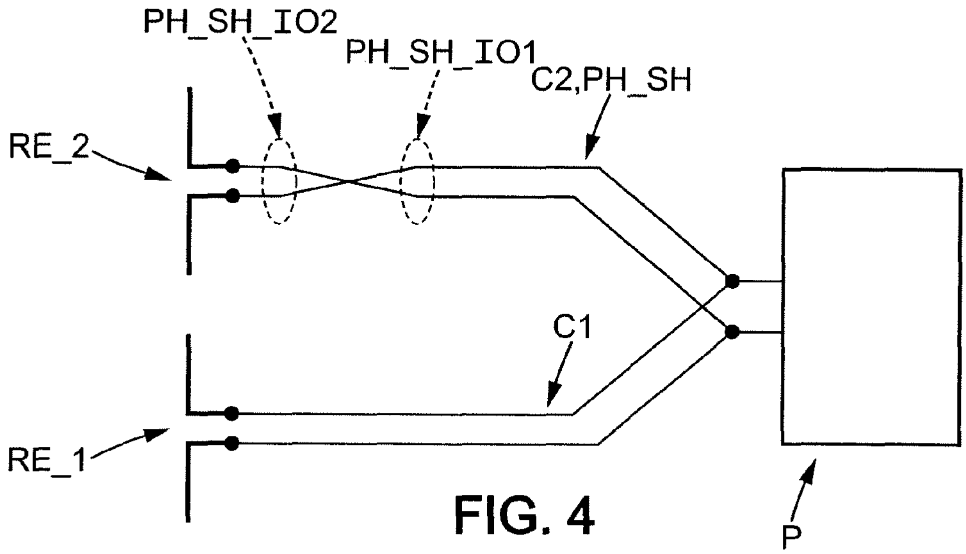

FIG. 4

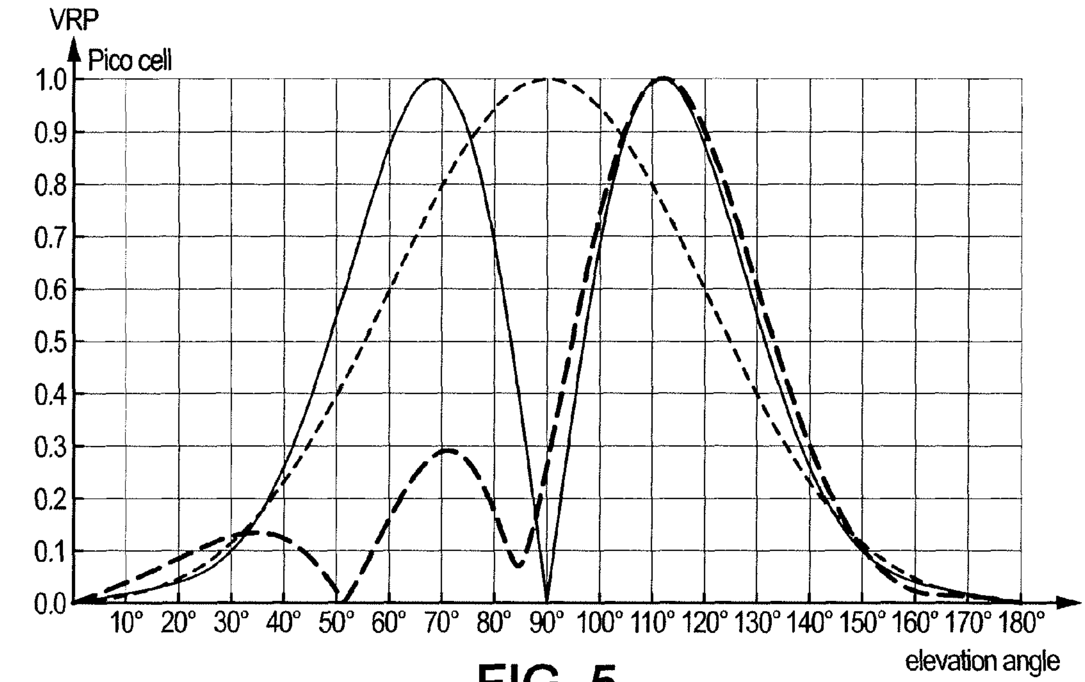
VRP
Pico cell
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150° 160° 170° 180°
elevation angle

FIG. 5

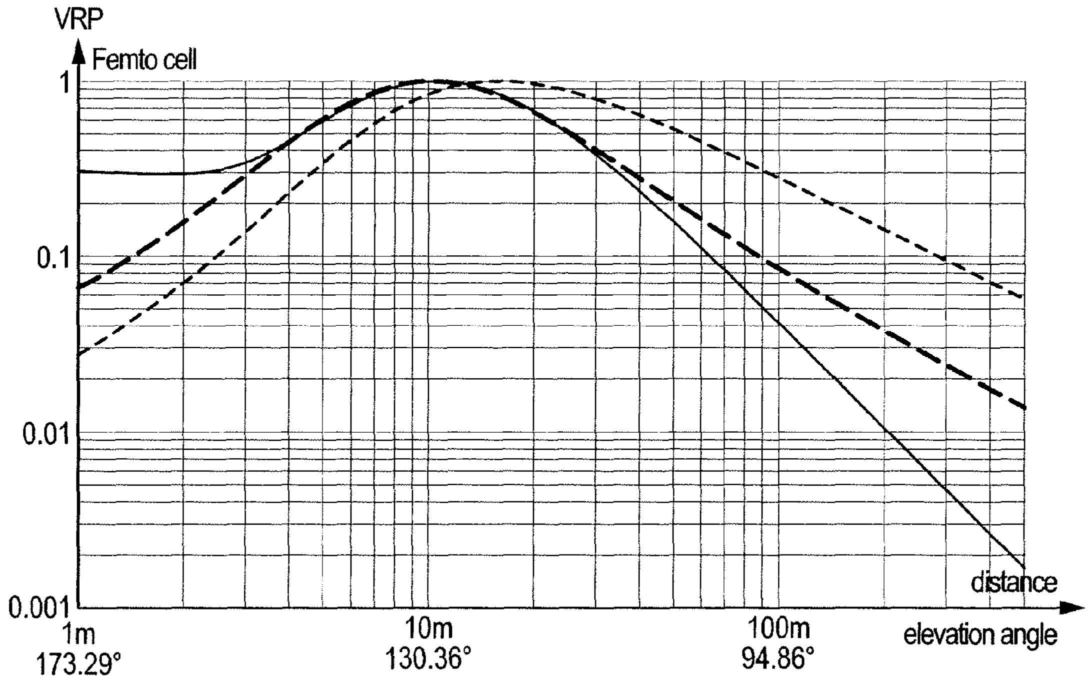
VRP
Femto cell
1
0.1
0.01
0.001
distance
1m
173.29°
10m
130.36°
100m
94.86°
elevation angle

FIG. 6

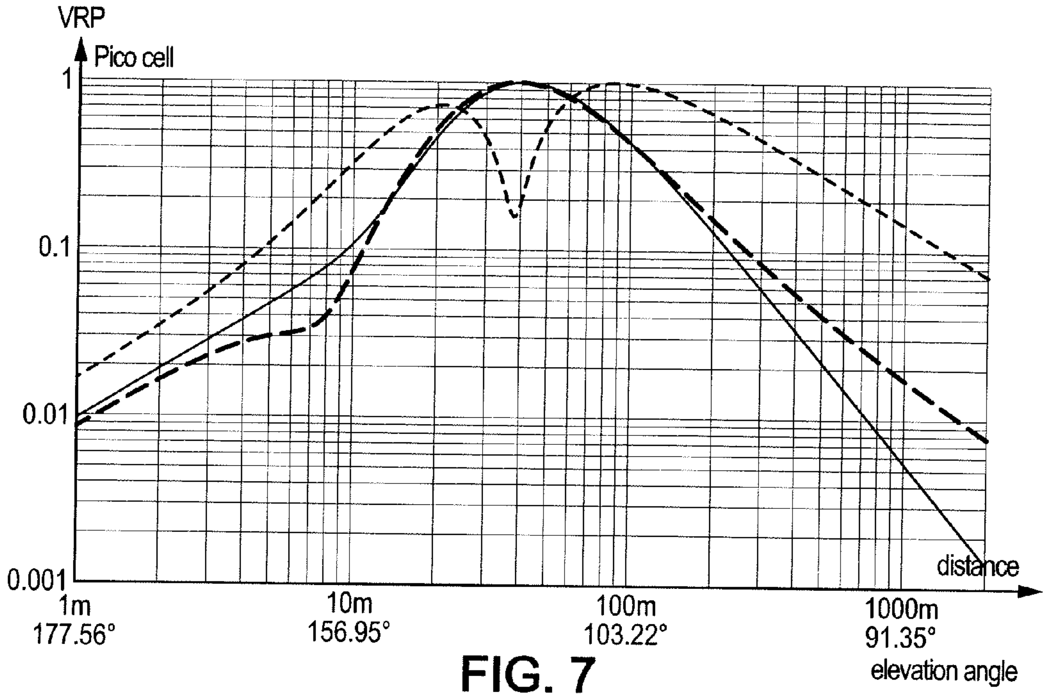
VRP
Pico cell
1
0.1
0.01
0.001
distance
1m
177.56°
10m
156.95°
100m
103.22°
1000m
91.35°
elevation angle

FIG. 7

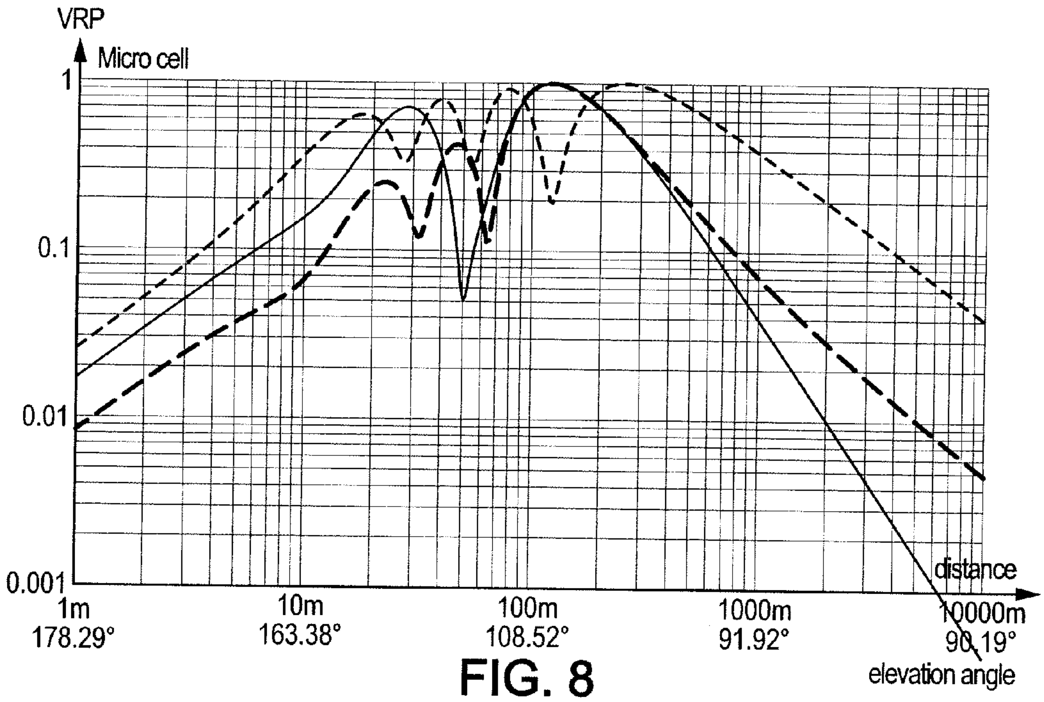
VRP
Micro cell
1
0.1
0.01
0.001
distance
1m
178.29°
10m
163.38°
100m
108.52°
1000m
91.92°
10000m
90.19°
elevation angle

FIG. 8

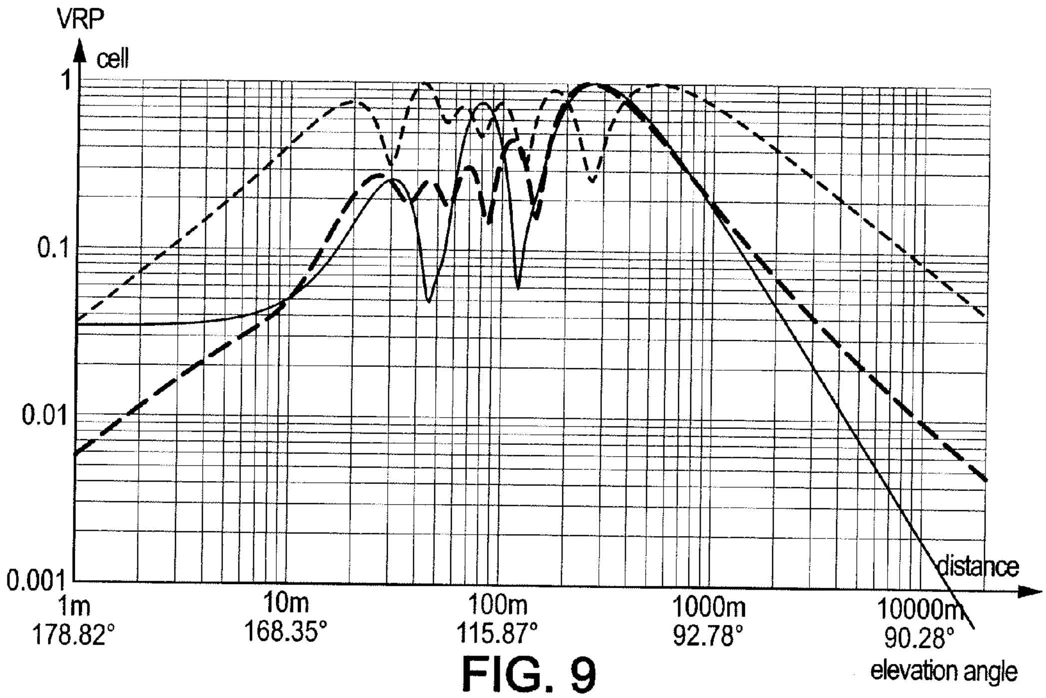
VRP
cell
1
0.1
0.01
0.001
distance
1m
178.82°
10m
168.35°
100m
115.87°
1000m
92.78°
10000m
90.28°
elevation angle

FIG. 9

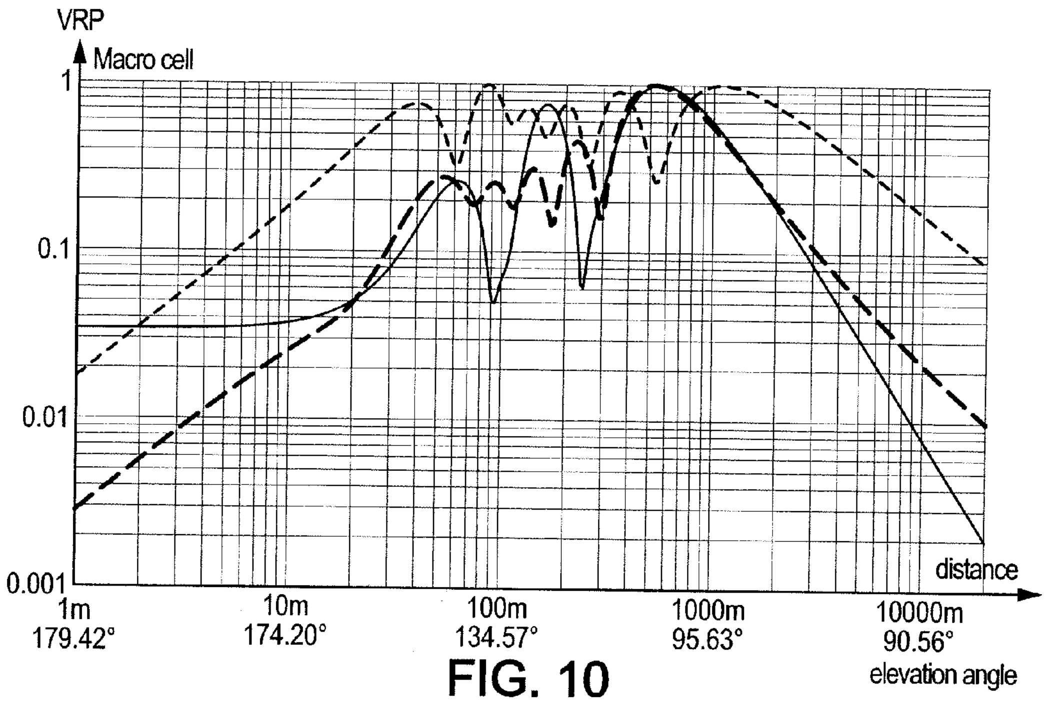
VRP
Macro cell
1
0.1
0.01
0.001
distance
1m
179.42°
10m
174.20°
100m
134.57°
1000m
95.63°
10000m
90.56°
elevation angle

FIG. 10

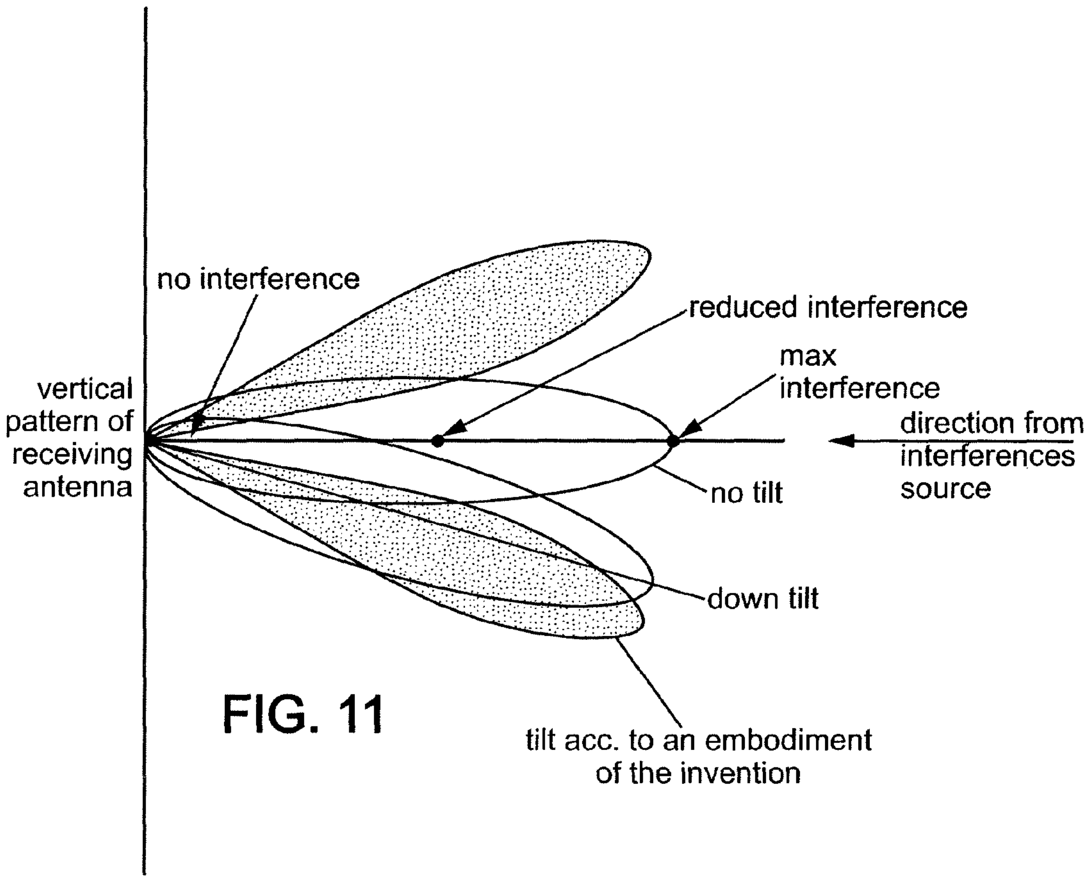
no interference
reduced interference
max
interference
vertical
pattern of
receiving
antenna
direction from
interferences
source
no tilt
down tilt
tilt acc. to an embodiment
of the invention

FIG. 11

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 11 29 0297

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2010/188289 A1 (MILANO ALBERTO [IL] ET AL) 29 July 2010 (2010-07-29) * paragraphs [0044], [0054] - [0056], [0062], [0080], [0084], [0087]; figures 1A, 2C,3B * -----	1-17	INV. H01Q1/24 H01Q21/10 H01Q21/29
X	US 6 208 313 B1 (FRANK PETER MICHAEL [CA] ET AL) 27 March 2001 (2001-03-27) * abstract; figures 7,8a * * column 4, paragraph 36-49 * -----	1-5,11, 13	

TECHNICAL FIELDS SEARCHED (IPC)

H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	6 December 2011	Jäschke, Holger

2

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 29 0297

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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06-12-2011

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US 2010188289 A1	29-07-2010	CA 2700465 A1	26-03-2009
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		WO 2009037692 A2	26-03-2009
US 6208313 B1	27-03-2001	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 4249181 A **[0004]**
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