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(54) **A CELLULAR RADIO ADAPTIVE ANTENNA ARRAY**

ADAPTIVES ANTENNENARRAY FÜR DEN ZELLULARFUNK

RESEAU CELLULAIRE D'ANTENNES ADAPTATIVES

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(73) Proprietor: **SIEMENS AKTIENGESELLSCHAFT
80333 München (DE)**

(72) Inventor: **TARRAN, Christopher John
Romsey, Hants SO51 6AR (GB)**

(74) Representative: **Payne, Janice Julia et al
Siemens AG,
Postfach 22 16 34
80506 München (DE)**

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Description

FIELD OF THE INVENTION

[0001] This invention relates to cellular radio communication systems and in particular relates to an antenna configuration for future generation cellular radio systems.

BACKGROUND TO THE INVENTION

[0002] Cellular radio systems are currently in widespread use throughout the world providing telecommunications to mobile users. Cellular radio systems are so-called because they divide a geographic area into cells; at the centre of each cell there is a base station through which mobile stations communicate, each base station typically being equipped with antenna arrays arranged in sectors. The distance between cells is determined such that co-channel interference is maintained at a tolerable level.

[0003] In order to provide services to an increasing number of wireless communications subscribers, with concomitant increasing risks of interference, the way forward is believed to be in adaptive smart antennas. That is to say, by appropriate amplitude and phase weighting, the base station beams from several antenna elements are steered, whereby strong beams are formed in the direction of the wireless communications subscriber, with nulls being steered in the direction of sources of interference. The result can provide an increase in range and an increase in capacity.

[0004] Whilst the potential advantages of adaptive smart antennas have been known for several years, there have been many problems encountered in making commercial examples, with problem such as cost and reliability. The tread nowadays is for increased reliability as prices are being reduced. Nevertheless, improvements are required in other areas: diversity gain, to name but one feature. Smart antennas have to date been constructed with their elements mounted a 0.5 wavelength spacing. This conventional approach provides for conventional beamforming but results in a small aperture for a given number of elements and is thus not good for spatial diversity. Alternatively some approaches have employed two such arrays with a wide spacing to provide diversity gain, however, such an array is sub optimal for adaptive nulling of interference and diversity gain is limited to little more that 2 element diversity. EP-A-1050923 (Lucent) discloses an antenna system having coherent and non-coherent receive characteristics. EP-A-7SS090 (Nortel) provides an antenna downlink beamsteering arrangement.

OBJECT OF THE INVENTION

[0005] The present invention seeks to provide an improved antenna array. In particular the present invention seeks to provide an antenna array with good diversity, gain and high directivity.

STATEMENT OF INVENTION

[0006] In accordance with a first aspect of the invention, there is provided an adaptive antenna adaptive antenna array comprising a plurality of parallel spaced apart linear antenna arrays, wherein the parallel spaced apart linear antenna arrays are arranged in adjacent first and second groups, the spacing between the linear antenna arrays of each group differs between the groups, the separation between the elements of the first group being of the order of 0.5 wavelength long and the separation of the elements in the second group being in the range of 1 -10 wavelengths long, characterised in that the array further comprises a third group of linear antenna arrays, the third group corresponding in spacing, between elements, to the second array and being positioned adjacent the first group such that the array is symmetrical about a central axis, the antennas being connected to a beamformer such that they are operable in both transmit and receive modes; and wherein the antenna array further comprises two further antenna arrays, corresponding in spacing, between elements, to the first array, each further array comprising four parallel linear arrays, and one array being positioned between two linear antenna arrays of the second and third arrays respectively, the further arrays being operable in transmit mode to support two-branch spatial diversity to provide FDD signalling

[0007] The antennas can be dipoles, flat-plate or other types. Preferably a reflector is provided to improve directivity and, in a sectored array configuration, to reduce interference between adjacent planar arrays.

[0008] The spacing between the adjacent antenna arrays can be greater than said spacing between the linear antenna arrays of the first group. The antenna array aperture can correspond to ten to twenty wavelengths in width.

[0009] The type of antenna elements can be selected from the group comprising, amongst others, dipole antenna elements and flat-plate antenna elements. A reflector can be provided, as appropriate, whereby to improve directivity and to reduce interference between adjacent planar arrays.

[0010] In accordance with a further aspect of the present invention, there is provided a method of operating an adaptive antenna array comprising a plurality of parallel spaced apart linear antenna arrays, wherein the parallel spaced apart linear antenna arrays are arranged in adjacent first, second and third groups, the second and third groups being arranged symmetrically about the first group, with the spacing between the linear antenna arrays of the first group being different from that of the second and third groups, the separation between the elements of the first group being of the order of 0.5. wavelengths long and the separation of the elements in the second and third groups being in the range of 1 - 10 wavelengths long, the method comprising the steps, in a receive mode, of receiving positional data of the subscriber and employing this data in beam forming means to appropriately determine the phase and amplitude weights whereby to direct the transmit and receive signals; and wherein there are provided two further antenna arrays, corresponding in spacing, between elements, to the first array, each further array comprising four parallel linear arrays, each of the second and third arrays having two antenna arrays with one further array being positioned therebetween, respectively wherein, in transmit mode, the antenna arrangement is operable to support two-branch spatial diversity to provide FDD signalling.

[0011] The present invention provides a novel array geometry for smart antennas having a large aperture which that provides good diversity gain, high directivity, good adaptive nulling of interference, good direction of arrival estimates and the ability to form a good sector beam for broadcast information. All these issues are desirable features of a cellular radio smart. The invention therefore provides good spatial diversity, which facilitates good resolution for space division multiple access systems.

BRIEF DESCRIPTION OF FIGURES

[0012] The invention may be understood more readily, and various other aspects and features of the invention may become apparent, from consideration of the following description and the accompanying drawing sheets, wherein:

Figure 1 shows a prior art antenna;
Figure 2 shows a schematic representation of a planar array made in accordance of invention;
Figure 3 shows a view of a first embodiment of the present invention;
Figure 4 is a graph showing comparative diversity gain figures for an antenna made in accordance with the invention;
Figure 5 shows a further embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] There will now be described, by way of example, the mode contemplated by the inventors for carrying out the invention. In the following description, numerous specific details are set out in order to provide a complete understanding of the present invention. It will be apparent, however, to those skilled in the art that the present invention may be put into practice with variations of the specific.

[0014] Figure 1 shows an example of a prior art antenna configuration wherein a base station 100 has three sectors and accordingly has three sets of planar arrays 102, each planar array comprising of six linear array antennas 104, the linear array antennas 104 being spaced apart by approximately half a wavelength, the central vertical axes of the array 102 being separated from each other by a distance of about ten wavelengths. It ,will be appreciated that these planar arrays 102 will provide adequate antenna beams but achieve limited diversity gain. That is to say, in a direction normal to the planar arrays, there will be a large antenna gain with no diversity gain, whereas in directions between planar arrays there will be a small antenna gain but a large diversity gain. Variants include the spacing apart of two such antenna arrays or single linear array antennas, whereby the antennas can provide good spatial diversity: the spacing between the arrays is typically of the order of ten wavelengths. This array, however, provides poor beamforming. In directions normal to the two branches for each sector, there is provided a medium antenna gain with a large diversity gain; in the direction corresponding to the division of each sector, there is a small antenna gain but a large diversity gain. Other forms of diversity are possible such as polarisation diversity. On the downlink, the same beam can be used on each polarisation with transmission diversity (STTD or TxAA) applied between the polarisations. In a direction normal to each array there will be a medium antenna gain and a large diversity gain, and, as above, in the direction between sectors there is a small antenna gain and a large diversity gain.

[0015] A first embodiment of the present invention shall now be described with reference to Figure 2, where there is shown an antenna arrangement 200 comprising an eight element antenna array 202. Each of the eight antenna elements 204 - 218 comprises a linear array 220 and the linear arrays are spaced in a parallel spaced apart fashion, as can best be seen from Figure 2. In the example shown in Figures 2 and 3, the antenna elements comprise co-linear dipole stacks. The array comprises three groups: a first, central group 230, comprising four antenna elements 208 - 214 which are approximately half a wavelength spaced apart to provide for a good sector coverage beam with phase only weighting; and second and third groups, 240, 250, comprising the remaining antenna elements are spread out from the centre, on either side. Symmetry about the centre provides for a mechanical centre of gravity at the centre. This can facilitate mounting of the antenna. Furthermore,. the antenna array, upon installation in the field, will be subject to extremes of weather: winds - which may be gale force - require the structure to be particularly stable. The second and third groups assist in providing good spatial diversity. A calibration network together with power amplifiers and low noise amplifiers mounted on the array is not shown.

[0016] The first array group 230 may comprise an odd number of linear arrays, and may, for example, comprise a group of three. The second and third groups may comprise, equally spaced antennas with two, three, four or more antennas. The particular number is not limited to the examples shown, but the choice of configuration will be determined by an appropriate cost performance ratio. In another embodiment, the array is asymmetrical and there is no third group of antennas. In such an embodiment, there exists on one side, a first group of closely spaced antennas and a second group of more widely spaced antennas.

[0017] The diversity gain aspect of the proposed non-uniform (irregular array) is illustrated in Figure 4. The top curve represents the response where there is a single antenna element, i.e. there is no smart antenna. The middle curve represents the response of a conventional 8 element regular array of 0.5 wavelength spacing. The bottom curve represents the response of an 8 element non-uniform array and considerably lower bit error rates (BER) can be achieved for a given value of Eb/No.

[0018] In a further embodiment, with reference to Figure 5, further transmit elements are provided, which could be of benefit for systems operating in a frequency division duplex mode such as UMTS WCDMA. The further transmit elements 502, 504 are mounted in the gaps of a basic array, between either the second and third group of antennas, although other positions would be possible. Two branch antenna diversity is enabled on the down link, as is required in accordance with the UMTS WCDMA standard. The two transmit arrays are electronically steered towards a user and then optimally combined whereby to provide optimal diversity. Four antenna elements are provided in each of the transmit arrays. As will be appreciated, the use of separate antenna elements for receive and transmit functions provides isolation and thus eases the design of the duplex filters.

[0019] In operation, the smart base station is operable to receive positional data from subscriber stations where by to appropriately phase and amplitude weight transmitted signals and receive signals, as is known. All of the antenna elements are conveniently employed, but it may be appropriate to reduce signal power for subscribers in close proximity, to reduce. radiated power and to reduce operating power of control circuitry within the base station. It will be appreciated that the wide aperture defined by the groups of antennas will improve spatial diversity reception in an economic fashion.

[0020] The geometry provides the following advantages: a large aperture (widely spaced elements) for good spatial diversity; high directivity (high ratio between gain in wanted direction to integral of gain in all directions); good interference nulling (an irregular array does not cause grating lobes, interference in the sidelobes can be nulled without collapse of the main beam); good direction of arrival estimates without ambiguity; good resolution for SDMA (space division multiple access); and, good 120 degree sector coverage broadcast beam possible by phase only weighting of the centre 0.5 wavelength spaced apart four elements

[0021] In Figure 3 the antenna array 230, 240 connects to a bank of digital transceiver equipments 232. The subsequent multi channel coherent data from each antenna element is processed by digital signal processing such as to apply phase and amplitude weightings to the array elements. These weightings can be calculated to apply beam patterns in the direction of wanted signals whilst providing pattern nulls in the directions of interference signals. In this way signal to interference plus noise ratio is maximised. In additions weightings are computed that provide optimum ration combining of the signals from each antenna.

[0022] In addition direction of arrival estimates are computed from the complete eight element array. The irregular nature of the array provides for good angle estimation and good adaptive nulling of interference without problems from grating lobes. The wide aperture provides for good resolution and good spatial diversity. The centre four elements of closely spaced elements (of the order of 0.5 lamda) are employed on transmit to provide a good 120 degree sector coverage beam for broadcast traffic.

[0023] With respect to the embodiment as illustrated in Figure 5, consideration is made to supporting FDD signals. There is a row of extra duplex filters between the array and the digital transceivers. On receive, the array operates as described above with reference to Figure 3. However, on transmit two extra four element arrays 502 and 504 are provided. These arrays facilitate 2 branch spatial downlink diversity which is a feature of the standard.

Claims

1. An adaptive antenna array comprising a plurality of parallel spaced apart linear antenna arrays, wherein the parallel spaced apart linear antenna arrays are arranged in adjacent first (230) and second (240) groups, the spacing between the linear antenna arrays of each group differs between the groups, the separation between the elements of the first group being of the order of 0.5 wavelength long and the separation of the elements in the second group being in the range of 1 -10 wavelengths long, **characterised in that** the array further comprises a third (240) group of linear antenna arrays, the third group corresponding in spacing, between elements, to the second array and being positioned adjacent the first group such that the array is symmetrical about a central axis; and wherein there are provided two further antenna arrays (502, 504), the further antenna arrays corresponding in spacing, between elements, to the first array, each further array comprising four parallel linear arrays and one array being positioned between two linear antenna arrays of the second and third arrays respectively, the further arrays being operable in transmit mode to support two-branch spatial diversity to provide FDD signalling.

2. An antenna array according to claim 1, wherein the spacing between the adjacent antenna arrays is greater than said spacing between the linear antenna arrays of the first group.

3. An antenna array according to claim 1, wherein the array aperture corresponds to ten to twenty wavelengths in width.

4. An antenna array in accordance with any preceding- claim, wherein the antenna elements are selected from the group comprising dipole antenna elements and flat-plate antenna elements.

5. An antenna configuration according to claim 1 or claim 2, wherein a reflector is provided whereby to improve directivity and to reduce interference.

6. A method of operating an adaptive antenna array comprising a plurality of parallel spaced apart linear antenna arrays, wherein the parallel spaced apart linear antenna arrays are arranged in adjacent first, second and third groups (230, 240), the second and third groups being arranged symmetrically about the first group, with the spacing between the linear antenna arrays of the first group being different from that of the second and third groups, the separation between the elements of the first group (230) being of the order of 0.5 wavelengths long and the separation of the elements in the second and third groups (240) being in the range of 1 - 10 wavelengths long, the method comprising the steps, in a receive mode, of receiving positional data of the subscriber and employing this data in beam forming means (232) to appropriately determine the phase and amplitude weights whereby to direct the transmit and receive signals; and wherein there are provided two further antenna arrays (502, 504), the further antenna arrays corresponding in spacing, between elements, to the first array, each further array comprising four parallel linear arrays, each of the second and third arrays having two antenna arrays with one further array (502, 504) being positioned therebetween, respectively wherein, in transmit mode, the antenna arrangement is operable to support two-branch spatial diversity to provide FDD signalling.

Patentansprüche

1. Adaptives Antennenarray, welches eine Vielzahl von parallelen, in Abständen voneinander angeordneten linearen Antennenarrays umfasst, wobei die parallelen, in Abständen voneinander angeordneten linearen Antennenarrays in einer ersten (230) und einer zweiten (240) Gruppe, die sich nebeneinander befinden, angeordnet sind, wobei der Abstand zwischen den linearen Antennenarrays in den beiden Gruppen unterschiedlich ist, wobei der Zwischenraum zwischen den Elementen der ersten Gruppe in der Größenordnung von 0,5 Wellenlängen liegt und der Zwischenraum der Elemente in der zweiten Gruppe im Bereich von 1 - 10 Wellenlängen liegt, **dadurch gekennzeichnet, dass** das Array ferner eine dritte (240) Gruppe von linearen Antennenarrays umfasst, wobei die dritte Gruppe hinsichtlich des Abstands zwischen den Elementen dem zweiten Array entspricht und so neben der ersten Gruppe angeordnet ist, dass das Array symmetrisch bezüglich einer Mittelachse ist; und wobei zwei weitere Antennenarrays (502, 504) vorgesehen sind, wobei die weiteren Antennenarrays hinsichtlich des Abstands zwischen den Elementen dem ersten Array entsprechen, wobei jedes weitere Array vier parallele lineare Arrays und ein Array, das zwischen den zwei linearen Antennenarrays des zweiten bzw. dritten Arrays angeordnet ist, umfasst, wobei die weiteren Arrays im Sendebetrieb so betrieben werden können, dass sie Raumdiversity mit zwei Zweigen (Two-branch Space Diversity) unterstützen und damit eine Signalisierung unter Verwendung des Frequenzduplex-Verfahrens (Frequency Division Duplex, FDD) ermöglichen.

2. Antennenarray nach Anspruch 1, wobei der Abstand zwischen den nebeneinander befindlichen Antennenarrays größer als der besagte Abstand zwischen den linearen Antennenarrays der ersten Gruppe ist.

3. Antennenarray nach Anspruch 1, wobei die Apertur des Arrays hinsichtlich der Breite zehn bis zwanzig Wellenlängen entspricht.

4. Antennenarray nach einem der vorhergehenden Ansprüche, wobei die Antennenelemente aus der Gruppe gewählt sind, welche Dipolantennen-Elemente und Flachantennen-Elemente umfasst.

5. Antennenkonfiguration nach Anspruch 1 oder Anspruch 2, wobei ein Reflektor vorgesehen ist, um dadurch die Richtwirkung zu verbessern und Störbeeinflussungen zu verringern.

6. Verfahren zum Betrieb eines adaptives Antennenarrays, welches eine Vielzahl von parallelen, in Abständen voneinander angeordneten linearen Antennenarrays umfasst, wobei die parallelen, in Abständen voneinander angeordneten linearen Antennenarrays in einer ersten, einer zweiten und einer dritten Gruppe (230, 240), die sich nebeneinander befinden, angeordnet sind, wobei die zweite und die dritte Gruppe symmetrisch um die erste Gruppe herum angeordnet sind, wobei der Abstand zwischen den linearen Antennenarrays der ersten

Gruppe von dem der zweiten und dritten Gruppe verschieden ist, wobei der Zwischenraum zwischen den Elementen der ersten Gruppe (230) in der Größenordnung von 0,5 Wellenlängen liegt und der Zwischenraum der Elemente in der zweiten und dritten Gruppe (240) im Bereich von 1 - 10 Wellenlängen liegt, wobei das Verfahren in einem Empfangsbetrieb die Schritte des Empfangens von Positionsdaten des Teilnehmers und des Verwendens dieser Daten in Strahlformungsmitteln (232), um auf geeignete Weise die Phasen- und Amplitudengewichte zu bestimmen und dadurch die Sende- und Empfangssignale zu richten, umfasst; und wobei zwei weitere Antennenarrays (502, 504) vorgesehen sind, wobei die weiteren Antennenarrays hinsichtlich des Abstands zwischen den Elementen dem ersten Array entsprechen, wobei jedes weitere Array vier parallele lineare Arrays umfasst, wobei das zweite und das dritte Array jeweils zwei Antennenarrays mit einem jeweils zwischen ihnen angeordneten weiteren Array (502, 504) aufweisen, wobei im Sendebetrieb die Antennenanordnung in der Lage ist, Raumdiversity mit zwei Zweigen (Two-branch Space Diversity) zu unterstützen und damit eine FDD-Signalisierung zu ermöglichen.

Revendications

1. Réseau d'antennes adaptatives consistant en une pluralité de réseaux d'antennes rectilignes espacés parallèlement les uns des autres, les réseaux d'antennes rectilignes espacés parallèlement les uns des autres étant agencés en un premier (230) et un deuxième (240) groupes adjacents, l'espacement entre les réseaux d'antennes rectilignes de chaque groupe différant entre les groupes, la séparation entre les éléments du premier groupe étant de l'ordre de 0,5 longueur d'onde de long et la séparation des éléments du deuxième groupe étant de l'ordre de 1-10 longueurs d'onde de long, **caractérisé en ce que** le réseau comprend par ailleurs un troisième (240) groupe de réseaux d'antennes rectilignes, le troisième groupe correspondant par l'espacement, entre les éléments, au deuxième réseau et étant positionné de façon adjacente au premier groupe de telle sorte que le réseau est symétrique autour d'un axe central, et deux réseaux d'antennes supplémentaires (502, 504) étant prévus, les réseaux d'antennes supplémentaires correspondant par l'espacement, entre les éléments, au premier réseau, chaque réseau supplémentaire comprenant quatre réseaux rectilignes parallèles et un réseau étant positionné entre deux réseaux d'antennes rectilignes, respectivement, des deuxième et troisième réseaux, les réseaux supplémentaires étant utilisables en mode d'émission pour prendre en charge la diversité d'espace à deux branches pour procurer une signalisation DRF.

2. Réseau d'antennes selon la revendication 1 dans lequel l'espacement entre les réseaux d'antennes adjacents est plus grand que ledit espacement entre les réseaux d'antennes rectilignes du premier groupe.

3. Réseau d'antennes selon la revendication 1, dans lequel l'ouverture du réseau correspond à dix à vingt longueurs d'onde en largeur.

4. Réseau d'antennes selon l'une quelconque des revendications précédentes, dans lequel les antennes élémentaires sont choisies dans le groupe constitué par des antennes élémentaires à dipôle et des antennes élémentaires planes.

5. Configuration d'antennes selon la revendication 1 ou la revendication 2, dans laquelle un réflecteur est prévu au moyen duquel améliorer la directivité et réduire le brouillage.

6. Procédé d'utilisation d'un réseau d'antennes adaptatives consistant en une pluralité de réseaux d'antennes rectilignes espacés parallèlement les uns des autres, les réseaux d'antennes rectilignes espacés parallèlement les uns des autres étant agencés en un premier, un deuxième et un troisième groupes (230, 240) adjacents, les deuxième et troisième groupes étant agencés symétriquement autour du premier groupe, l'espacement entre les réseaux d'antennes rectilignes du premier groupe étant différent de celui des deuxième et troisième groupes, la séparation entre les éléments du premier groupe (230) étant de l'ordre de 0,5 longueur d'onde de long et la séparation des éléments des deuxième et troisième groupes (240) étant de l'ordre de 1-10 longueurs d'onde de long, le procédé comprenant les étapes consistant, en mode de réception, à recevoir des données positionnelles de l'abonné et à employer ces données dans le moyen de conformation de faisceau (232) pour déterminer de manière appropriée les pondérations de phase et d'amplitude avec lesquelles orienter les signaux d'émission et de réception, et deux réseaux d'antennes supplémentaires (502, 504) étant prévus, les réseaux d'antennes supplémentaires correspondant par l'espacement, entre les éléments, au premier réseau, chaque réseau supplémentaire comprenant quatre réseaux rectilignes parallèles, chacun des deuxième et troisième réseaux comportant deux réseaux d'antennes, un réseau supplémentaire (502, 504) étant positionné, respectivement, entre eux, l'agencement d'antennes étant, en mode d'émission, utilisable pour prendre en charge la diversité d'espace à deux branches pour procurer une signalisation par DRF.

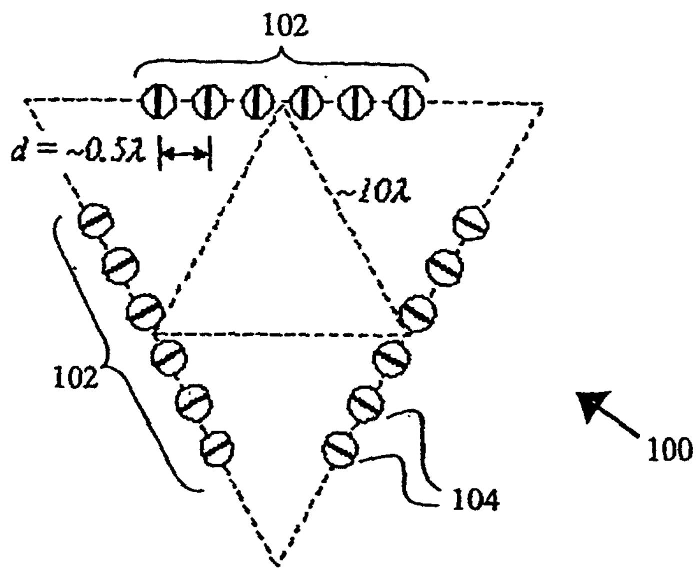

Figure 1

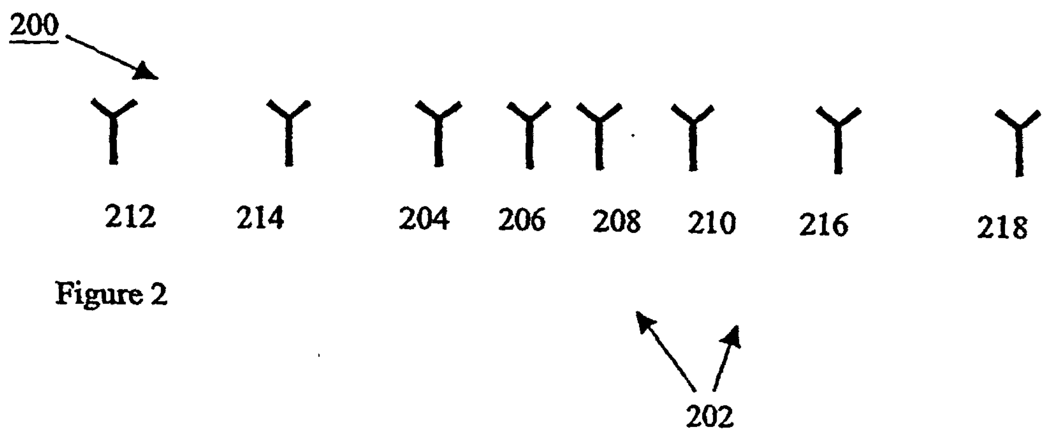

Figure 2

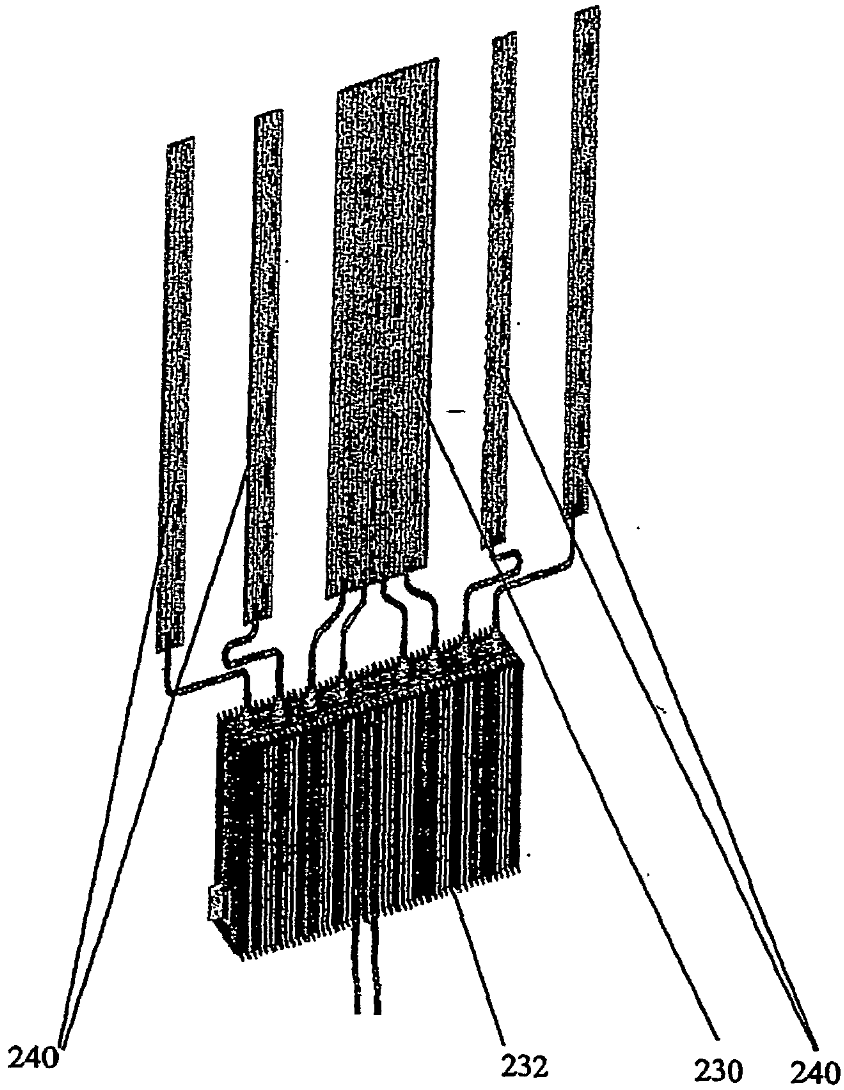

Figure 3

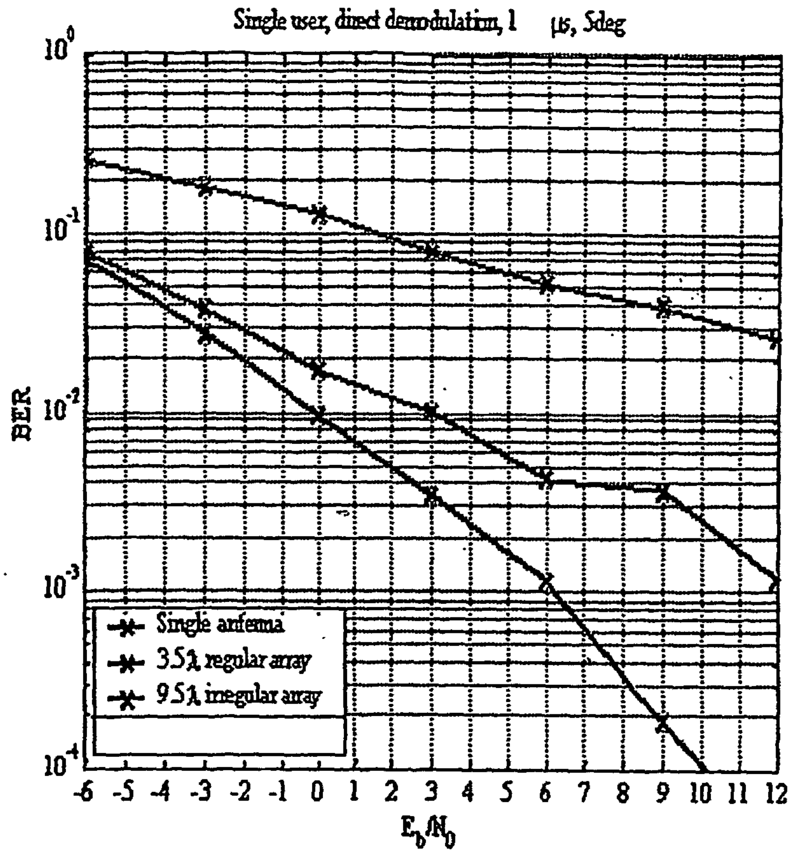
Single user, direct demodulation, 1 μs, 5deg
BER
E_b/N_0
Single antenna
3.5λ regular array
9.5λ irregular array

Figure 4

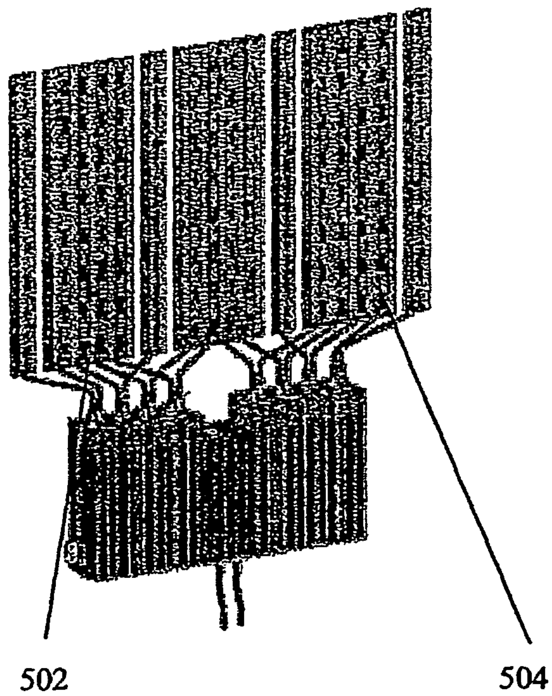

Figure 5