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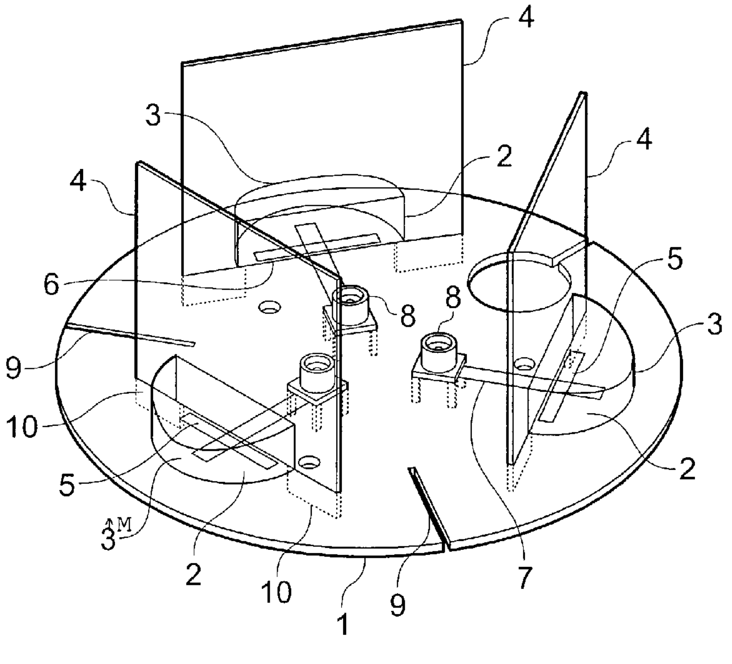

(57) Abstract: There is disclosed a dielectric resonator antenna array comprising three dielectric resonator elements (2) each having a feed (5, 7) for transferring energy into and out of the dielectric resonator element (2), each element (2) being configured to emit more radiation in a given first direction than in an opposed second direction, and wherein the elements (2) are arranged in a triangular configuration with the first directions facing outwardly.

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LOCATION MONITORING UNIT

The present invention relates particularly, but not exclusively, to an array of dielectric resonator antennas (DRAs) having a generally triangular configuration, although other non-triangular configurations are also proposed. The invention also extends to the use of high dielectric antennas (HDAs) as well as to DRAs. The invention is particularly, though not exclusively, directed towards a special purpose antenna called a Location Monitoring Unit (LMU).

LMUs may be used as an additional antenna to be fitted to mobile communication base-stations as a component of a new system for finding accurate locations for mobile telecommunications handsets and the like. The LMU is a receive-only three-sector antenna system used to monitor the signal from other base-stations. Only one antenna element is generally used at a time, and a switching arrangement may be is provided to connect the output between the antenna elements.

Dielectric resonator antennas (DRAs) are resonant antenna devices that radiate or receive radio waves at a chosen frequency of transmission and reception, as used in for example in mobile telecommunications. In general, a DRA consists of a volume of a dielectric material disposed on or close to a grounded substrate, with energy being transferred to and from the dielectric material by way of monopole probes inserted into the dielectric material or by way of monopole aperture feeds provided in the grounded substrate (an aperture feed is a discontinuity, generally rectangular in shape, although oval, oblong, trapezoidal or butterfly/bow tie shapes and combinations of these shapes may also be appropriate, provided in the grounded substrate where this is covered by the dielectric material. The aperture feed may be excited by a strip feed in the form of a microstrip transmission line, coplanar waveguide, slotline or the like which is located on a side of the grounded substrate remote from the dielectric material). Direct connection to and excitation by a microstrip transmission line is also possible. Alternatively, dipole probes may be inserted into the dielectric material, in which case a grounded substrate is not required. By providing multiple feeds and exciting these sequentially or in various combinations, a continuously or incrementally steerable beam or beams may be formed, as discussed for example in the present applicant's co-pending US patent application serial number US 09/431,548 and the publication by KINGSLEY, S.P. and O'KEEFE, S.G., "Beam steering and monopulse processing of probe-fed dielectric resonator antennas", IEE Proceedings - Radar Sonar and Navigation, 146, 3, 121 - 125, 1999, the full contents of which are hereby incorporated into the present application by reference.

High dielectric antennas (HDAs) are similar to DRAs, but instead of having a full ground plane located under the dielectric pellet, HDAs have a smaller ground plane or no ground plane at all. Removal of the ground plane underneath gives a less well-defined resonance and consequently a very much broader bandwidth. HDAs generally radiate as much power in a backward direction as they do in a forward direction, and are therefore less suited than DRAs for constructing antenna arrays, but useful arrays of HDAs may still be formed.

The resonant characteristics of a DRA or HDA depend, *inter alia*, upon the shape and size of the volume of dielectric material (e.g. a dielectric pellet) and also on the shape, size and position of the feeds thereto. It is to be appreciated that in a DRA or HDA, it is the dielectric material that resonates when excited by the feed. This is to be contrasted with a dielectrically loaded antenna (DLA), in which a traditional conductive radiating element is encased in a dielectric material that modifies the resonance characteristics of the radiating element.

In both DRAs and HDAs, the primary radiator is the dielectric pellet. In DLAs, the primary radiator is a conductive component (e.g. a metal wire or printed strip or the like), and a dielectric component then just modifies the medium in which the DLA operates and generally allows the antenna as a whole to be made smaller or more compact.

DRAs and HDAs may take various forms, a common form having a cylindrical shape which may be fed by a metallic probe within the cylinder. Such a cylindrical resonating medium can be made from several candidate materials including ceramic dielectrics.

Since the first systematic study of dielectric resonator antennas (DRAs) in 1983 [LONG, S.A., McALLISTER, M.W., and SHEN, L.C.: "The Resonant Cylindrical Dielectric Cavity Antenna", IEEE Transactions on Antennas and Propagation, AP-31, 1983, pp 406-412], interest has grown in their radiation patterns because of their high radiation efficiency, good match to most commonly used transmission lines and small physical size [MONGIA, R.K. and BHARTIA, P.: "Dielectric Resonator Antennas - A Review and General Design Relations for Resonant Frequency and Bandwidth", International Journal of Microwave and Millimetre-Wave Computer-Aided Engineering, 1994, 4, (3), pp 230-247].

The majority of configurations reported to date have used a slab of dielectric material mounted on a ground plane (grounded substrate) excited by either an single aperture feed in the ground plane [ITTIPIBOON, A., MONGIA, R.K., ANTAR, Y.M.M., BHARTIA, P. and CUHACI, M: "Aperture Fed Rectangular and Triangular Dielectric Resonators for use as Magnetic Dipole Antennas", Electronics Letters, 1993, 29, (23), pp 2001-2002] or by a single probe inserted into the dielectric material [McALLISTER, M.W., LONG, S.A. and CONWAY G.L.: "Rectangular Dielectric Resonator Antenna", Electronics Letters, 1983, 19, (6), pp 218-219]. Direct excitation by a transmission line has also been reported by some authors [KRANENBURG, R.A. and LONG, S.A.: "Microstrip Transmission Line Excitation of Dielectric Resonator Antennas", Electronics Letters, 1994, 24, (18), pp 1156-1157].

Several authors have already explored the concept of using a series of DRAs to build an antenna array. For example, an array of two cylindrical single-feed DRAs has been demonstrated [CHOW, K.Y., LEUNG, K.W., LUK, K.M. AND YUNG, E.K.N.: "Cylindrical dielectric resonator antenna array", Electronics Letters, 1995, 31, (18), pp 1536-1537] and then extended to a square matrix of four DRAs [LEUNG, K.W., LO, H.Y., LUK, K.M. AND YUNG, E.K.N.: "Two-dimensional cylindrical dielectric resonator antenna array", Electronics Letters, 1998, 34, (13), pp 1283-1285]. A square matrix of four cross DRAs has also been investigated [PETOSA, A., ITTIPIBOON, A. AND CUHACI, M.: "Array of circular-polarized cross dielectric resonator antennas", Electronics Letters, 1996, 32, (19), pp 1742-1743]. Long linear arrays of single-feed DRAs have also been investigated with feeding by either a dielectric waveguide [BIRAND, M.T. AND GELSTHORPE, R.V.: "Experimental millimetric array using dielectric radiators fed by means of dielectric waveguide", Electronics Letters, 1983, 17, (18), pp 633-635] or a microstrip [PETOSA, A., MONGIA, R.K., ITTIPIBOON, A. AND WIGHT, J.S.: "Design of microstrip-fed series array of dielectric resonator antennas", Electronics Letters, 1995, 31, (16), pp 1306-1307]. This last research group has also found a method of improving the bandwidth of microstrip-fed DRA arrays [PETOSA, A., ITTIPIBOON, A., CUHACI, M. AND LAROSE, R.: "Bandwidth improvement for microstrip-fed series array of dielectric resonator antennas", Electronics Letters, 1996, 32, (7), pp 608-609]. A study has also been made recently of different configurations that can be used to form cylindrical dielectric resonator antenna broadside arrays [WU, Z.; DAVIS, L.E. AND DROSSOS, G.: "Cylindrical dielectric resonator antenna arrays", Proceedings of the 11th International Conference on Antennas and Propagation, 2001, p. 668.]

A method of disposing array elements in a closely packed arrangement has been disclosed by the present applicant in GB 2 360 133 [Multi-segmented dielectric resonator antenna] in which the geometry of a circular array of elements is matched to the geometry of the elements in order to obtain the maximum element packing.

A method of disposing array elements in a closely packed, essentially orthogonal, arrangement of transmit and receive elements has been disclosed by the present applicant in GB patent application no 0205739.6 [Novel dielectric resonator antenna with transmitting and receiving elements]. Further GB patent applications for other array geometries have been made by the present applicant, including GB patent applications no 0207052.2 [Novel dielectric resonator antenna resonance modes].

None of these publications and patent applications disclose the concept put forward in the present application, which is that of developing a specific antenna array to meet a particular product requirement and to have one or more of a set of preferred properties including:

1. Vertical polarisation
2. A division of azimuth space into three sectors
3. Good gain and bandwidth
4. Good front-to-back ratio to distinguish signals coming from behind the antenna from those coming from the front
5. High isolation between elements so that three can be packed into a small space and still make independent observations in three directions
6. A variety of different dielectric geometries that can be used so as to tailor the beamwidth, gain and bandwidth of each sector to different communication networks and applications

The results set out in the present application are intended to show that antenna elements in embodiments of the present invention work better in an array than they do individually, thereby enhancing the properties 2 to 5 above.

Up until now, LMU antennas have been omni-directional in the azimuth plane, but there are operational advantages to having a three-sector system. With an omnidirectional antenna the various multipath signals from a distant base station can cause cancellation of the signal. This situation can be avoided with a sectored system by switching sectors. Sector switching can also be used to minimise or reduce interfering signals and to improve measurement accuracy on weak base station signals, especially when there is no direct line of sight.

For the purposes of the present application, the expression "dielectric antenna" is hereby defined as encompassing DRAs and HDAs.

According to a first aspect of the present invention, there is provided a dielectric antenna array comprising three dielectric resonator elements each having at least one feed for transferring energy into and out of the dielectric resonator element, wherein each element is configured to emit more radiation in a given first direction than in an opposed second direction, and wherein the elements are arranged in a triangular configuration with the first directions facing outwardly.

According to a second aspect of the present invention, there is provided a dielectric antenna array comprising at least two dielectric resonator elements each having at least one feed for transferring energy into and out of the dielectric resonator element, wherein each element is configured to emit more radiation in a given first direction than in an opposed second direction, and wherein the elements are arranged in a configuration such that the first directions face mutually outwardly from a central point of the array.

It will be apparent that embodiments of the second aspect of the present invention need not have a triangular array configuration when other than three dielectric resonators are used.

The elements may be shaped so as each to have a radiation front lobe that is greater than a radiation back lobe. Alternatively or in addition, one or more of the elements may be provided with a conductive back plane or wall so as to reduce the size of the backlobe.

In one particularly preferred embodiment of the present invention, each dielectric resonator element has a half cylindrical configuration with a curved front face, a generally planar rectangular rear face and two opposed substantially planar and generally semi-circular side faces. In some embodiments, one generally semi-circular face may be sloped relative to the other, for example by chamfering a top surface of the element so that it slopes downwardly from the rear face, which may provide improved bandwidth. Each element is provided with a conductive back plane that contacts or is in close proximity with the rear face and substantially parallel thereto. The elements are arranged with one semi-circular face on or close to a grounded generally planar substrate, with the conductive back planes electrically contacting the grounded substrate and disposed generally perpendicular thereto in a triangular formation. It is particularly preferred that the back planes be disposed in a substantially equilateral triangular configuration, although other configurations may be appropriate for certain applications. The dielectric resonator elements are disposed such that they face mutually outwardly with respect to the conductive back planes.

An alternative preferred configuration uses quarter split cylindrical dielectric resonator elements, with two generally planar rectangular surfaces adjoining each other substantially at a right angle, a curved surface, and two opposed generally planar quarter circular side faces. The conductive back planes and the grounded substrate are configured as before, and the dielectric resonator elements are disposed such that the generally rectangular surfaces of each element contact or are close to respectively the back plane and the grounded substrate. Instead of using a common grounded substrate for all of the dielectric resonator elements, each element may have its own grounded substrate contacting or disposed close to one of the rectangular surfaces, with a conductive back plane contacting or disposed close to the other rectangular surface. In this way, each dielectric resonator element may be angled such that both its grounded substrate and its conductive back plane are disposed at an angle of about 45° to a plane in which the apexes of all of the dielectric resonator elements are disposed, i.e. bisecting the curved face of each dielectric resonator element so as to achieve improved gain in an azimuth direction. These alternative configurations provide improved bandwidth than the array of half cylindrical elements discussed above, but at a cost of slightly lower peak gain.

It will be apparent to the skilled reader that other dielectric resonator element shapes may be used where appropriate, and that the array may be formed from elements not all having the same shape.

In the configurations described above, the dielectric resonator elements are advantageously each provided with a feed in the form of a slot in the grounded substrate located under the conductive back plane and generally parallel thereto, preferably located on an outer (with respect to the array) side of the conductive wall and running along its edge. The slot is preferably provided with a transmission line running generally perpendicular to the slot on an underside of the grounded substrate.

Alternative feed mechanisms, including probes (located inside or adjacent to the elements) and microstrip transmission lines, may alternatively be used.

When the triangular array of the present invention is configured as an equilateral triangular array, each element serves a 120° sector in azimuth.

The present applicant has found, surprisingly, that an array of dielectric resonator elements as defined above has improved operational characteristics with respect to each individual element. In particular, azimuth space is divided into three sectors, and the array has improved gain and bandwidth, a good front-to-back ration of radiation patterns and high isolation between elements.

In a further aspect, embodiments of the present invention also relate to reducing interference from a transmitter, such as a mobile telecommunications base station, at a receiving antenna, such as a location monitoring unit (LMU), located nearby.

There is an ongoing requirement for mobile communications companies to develop ways of locating handsets. One technique being developed by a number of companies is to make use of receive-only LMUs that detect signals from distant base stations on the same network and monitor the timing and synchronisation of the network. This means that LMUs are necessarily tuned to base station transmitter frequency bands. To avoid the cost of building an entirely new infrastructure for the LMU antennas, they are to be placed on existing base station towers, sufficiently high up so as to be able to get the best line of sight radio path to other base-stations. This near co-location of sensitive LMU receiving systems with powerful transmitters operating in the same band means that the LMU cannot have active radio frequency (RF) circuitry such as amplifiers without these being driven into non-linear operation or even suffering damage.

Building an LMU with only antennas and switching components and no RF amplification leads to a requirement for expensive low-loss components such as the RF cable that connects the LMU to the base station equipment on the ground. This in turn drives up the cost of the LMU, as well as restricting its performance.

Typically, a single RF cable links the LMU on a base station tower to the base station equipment therebelow. DC power and switching information are sent up the cable and RF signals are sent back down. The purchase and installation costs of this cable are one of the main costs of the LMU. The LMU preferably includes switching electronics so as to be able to process signals received by each of the dielectric resonator elements (where more than one is provided) and to distinguish between them (so as, for example, to provide remote base station and thus handset location information). It is to be noted that the base stations detect the handsets and locate them by triangulation, but the base stations can only do this if they are synchronised - the LMU provides the synchronisation information.

According to a third aspect of the present invention, there is provided a telecommunications mast having an upper end and a lower end, with a transmitting antenna at an upper region thereof and a location monitoring unit (LMU) mounted intermediate the transmitting antenna and the lower end of the mast, the LMU being comprised as a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein the LMU is mounted with the grounded substrate positioned between the at least one dielectric resonator element and the transmitting antenna.

According to a fourth aspect of the present invention, there is provided a location monitoring unit (LMU) comprising a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein a second side of the grounded substrate opposed to the first side thereof is provided with a layer of a radio wave absorbing material.

In this way, it is possible to reduce interference in the LMU from signals transmitted by the transmitting antenna. In the third aspect of the present invention, this is achieved by way of the grounded substrate acting as a shield between the dielectric resonator elements, and also by taking advantage of the elevation radiation pattern of the LMU, which is less sensitive to signals emanating from the side of the grounded substrate opposed to the side on which the at least one dielectric resonator element in located. In the fourth aspect of the present invention, the radio wave absorbing material helps further to isolate the at least one dielectric resonator element from signals impinging on the second side of the grounded substrate.

According to a fifth aspect of the present invention, there is provided a location monitoring unit (LMU) comprising a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein a second side of the grounded substrate opposed to the first side thereof is provided with a sensing antenna adapted to receive at least a proportion of an interfering radio signal.

The LMU of the third and fourth aspects of the present invention may also additionally be provided with a sensing antenna located on the side of the grounded substrate opposed to the side on which the at least one dielectric resonator element is located (i.e. the side facing the transmitting antenna of the telecommunications mast when the LMU is mounted thereon).

The sensing antenna is adapted to receive at least (and preferably) a small amount of a signal transmitted by the transmitting antenna of the mast. The sensing antenna is preferably a small low-gain antenna adapted to pick up a small proportion of an interfering signal emanating from the transmitting antenna, but being relatively insensitive to signals from remote base stations that the dielectric resonator antenna of the LMU is designed to receive (generally in a substantially horizontal direction relative to the telecommunications mast when erected).

Appropriate switching electronics provided in the LMU or connected thereto may be adapted to analyse, or pre-set, a phase and amplitude of the interfering signal received by the sensing antenna and to apply a cancellation signal (being, for example, in antiphase to the interfering signal and with the same amplitude) to the at least one feed of the LMU. The switching electronics may actively generate an independent cancellation signal, or they may attenuate or amplify or otherwise process the received interfering signal so as to generate an appropriate cancellation signal. It is preferred that conducting lines carrying the cancellation signal are relatively short so as not unduly to restrict an operational bandwidth of the LMU.

The LMU of the fourth and fifth aspects of the present invention may be mounted on a telecommunications mast as set out in the third aspect of the invention.

The LMU of all the aspects of the present invention may additionally be provided with a grounded conductive baseplate or the like in addition to the grounded substrate on which the dielectric resonators are mounted. The baseplate may be made out of aluminium or any other appropriate conductive material, and is preferably located on a side of the grounded substrate opposed to the side on which the dielectric resonators are mounted. The baseplate may serve as a platform on which the LMU is mounted and by way of which it may be attached or mounted on a telecommunications mast or other structure. The baseplate can help to absorb or reduce interfering radio signals at the LMU, especially when it is located between the LMU and a transmitting antenna on a telecommunications mast.

By way of embodiments of the present invention, it is possible to improve isolation between a transmitting antenna and an LMU both mounted on a telecommunications mast. As a result, it is then possible to use low noise amplifiers in the switching electronics of the LMU so as to provide a number of advantages, including lower losses, a wider impedance match and a lower link budget noise figure. As a result, it is then possible to use thinner and/or lower cost RF cable in the telecommunications mast and also to use more complex switching electronics so as to add further functionality to the LMU. In other words, by sufficiently attenuating the interfering signal from the transmitting antenna of the telecommunications mast, sensitive low noise amplifiers can be used in the LMU for the detection of the wanted signals from distant base stations.

The various embodiments of the third, fourth and fifth aspects of the present invention disclosed in the present application generally seek to improve a front-to-up ratio of an LMU (when mounted on a telecommunications mast with a transmitting antenna located higher up the mast than the LMU) so that it has lower sensitivity to interfering signals emanating from above. Without relatively high isolation between the LMU and the transmitting antenna of the mast, there exists a severe filtering problem within the LMU radio receiver electronics.

For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made by way of example to the accompanying drawings, in which:

FIGURE 1 shows a perspective view of an embodiment of a DRA array of the present invention;

FIGURE 2 shows a plan view of the array of Figure 1;

FIGURE 3 shows an elevation radiation pattern in dBi of a single DRA element in isolation;

FIGURE 4 shows an azimuth pattern in dBi of a single DRA element in isolation;

FIGURE 5 shows an azimuth pattern in dBi of a single DRA element located next to another DRA element, the other DRA element not being activated;

FIGURE 6 shows an azimuth pattern in dBi of a single DRA element located in the array of Figures 1 and 2, with the other two DRA elements not being activated;

FIGURE 7 shows a computer-simulated azimuth pattern in dBi of a single DRA element located in the array of Figures 1 and 2, with the other two DRA elements not being activated;

FIGURE 8 shows a comparison between S_{11} return loss against frequency for a single DRA element in isolation and a single DRA element as part of the array of Figures 1 and 2;

FIGURE 9 shows a comparison between an azimuth radiation pattern in dBi for a single DRA element in isolation and a single DRA element as part of the array of Figures 1 and 2.

FIGURE 10 shows a further azimuth radiation pattern for one of the DRA elements of the LMU of Figure 1;

FIGURE 11 shows a further elevation radiation pattern for one of the DRA elements of the LMU of Figure 1;

FIGURE 12 shows an LMU embodying an aspect of the present invention; and

FIGURE 13 shows two LMUs each mounted on a telecommunications mast.

Figures 1 and 2 show a DRA array comprising a grounded substrate 1 on which are disposed three generally half cylindrical dielectric resonator elements 2, which may be made out of ceramics or other dielectric materials. The elements 2 are located in an equilateral triangular configuration with their curved faces 3 facing outwardly. Each element 2 is provided with an electrically conductive back plane 4 that electrically contacts the grounded substrate 1 by way of tabs 10 passing therethrough and is disposed generally at right angles thereto. The back planes 4 are disposed such that each is angled at 60° to its respective neighbours in a plane parallel to the grounded substrate 1.

Each element 2 has a feed comprising a slot or aperture 5 in the grounded substrate 1, the slot or aperture 5 extending parallel to the back plane 4 and located under a rear edge 6 of the element 2. Each slot or aperture 5 is provided with a transmission line 7 that runs underneath the grounded substrate 1 (but is electrically isolated therefrom) and crosses underneath the slot or aperture 5 substantially at right angles thereto. Sockets 8 are provided on a central part of the grounded substrate 1 so as to allow electrical inputs to the transmission lines 7.

In addition, radial slits 9 may be provided in the grounded substrate 1 between the back planes 4 so as to improve isolation between the elements 2.

Figure 3 shows an elevation radiation pattern in dBi of a single element 2 with back plane 4 measured at 1827 MHz in isolation (i.e. with no other elements 2 or back planes 4 present on the grounded substrate 1). Positions above the origin 11 on the pattern represent spatial positions above the element 2, and positions below the origin 11 represent spatial positions below the element 2. Positions to the left of the origin 11 represent maximum gain horizontally and positions to the right represent a horizontal back lobe 12. The peak gain is 4.3dBi.

Figure 4 shows an azimuth pattern in dBi for the same single element 2 as Figure 3. The peak gain is 4.5dBi and the beamwidth is roughly 90 degrees to the –3dB points. The front-to-back ratio (an important parameter for this antenna that is intended to distinguish multipath communications signals arriving from different directions) is about 12.5dB.

Figure 5 shows the azimuth pattern in dBi for the same element 2 as in Figures 3 and 4, but this time with one other element 2 present (but not activated). The peak gain has now improved to 4.8dBi and the front-to-back ratio has improved dramatically to about 32dB. The beamwidth is substantially unchanged.

Figure 6 shows the azimuth pattern in dBi for the same element as in Figures 3, 4 and 5 but this time with both the other elements 2 present (but not activated). The peak gain has improved further to 5.1dBi. Although the front-to-back ratio at 20dB is not as good as in Figure 5, it is still a significant improvement over the case for a single element 2 in isolation. Again, the beamwidth is substantially unchanged.

As a confirmation that the unexpected improvements in gain and front-to-back ratio is a real result, Figure 7 shows a computer simulation of the LMU array azimuth pattern with both the other elements 2 present (but not activated). It can be seen that Figure 7 exhibits a similar shape to the measurements presented in Figures 4, 5 and 6 and that the antenna is performing in real life much as computer modelling predicts.

A direct comparison of the patterns formed using the full LMU array and an isolated element 2 with back plane 4 can be seen in Figures 8 and 9. Again, this confirms that the isolated element 2 performs differently when it is in the presence of the other LMU elements 2.

The isolation between any pair of the three elements 2 in the LMU array is 30dB. This result would not be expected from the azimuth pattern of a single element 2 (see Figure 4) and arises from the lower back lobes that occur when an element 2 is operated with the other two elements 2 present. This result can be derived by inspection of Figures 4, 5 and 6 by reading the power 120 degrees round from the peak gain direction, i.e. in the direction of the next element 2.

With many antenna systems, the far field patterns shown in Figures 4, 5 and 6 could not be used to calculate coupling to another nearby element 2 because such an element 2 would be in the near field (in which case, coupling would be very high). A special property of DRAs is that the near field/far field boundary lies close to the surface of the dielectric material and thus a far field null, or any low gain part of the pattern, means that low coupling will occur if another element 2 is placed in that direction and is more than several millimetres away. This special property of DRAs underpins the design of the LMU 3-segment antenna; it would be difficult to engineer such a compact three-way structure using conventional antenna elements.

Figure 10 shows the azimuth radiation pattern of one of the three LMU antenna elements 2; the other two patterns are disposed 120° to the left and right of this one.

The elevation radiation pattern of one of the three LMU antenna elements 2 is shown in Figure 11. It can be seen that although the antenna element 2 radiates predominantly in the horizontal direction, it has significant sensitivity to radiation arriving from above, but less sensitivity to radiation arriving from below.

Figure 12 shows a currently preferred embodiment of the LMU of the fifth aspect of the present invention comprising a grounded substrate 1 on which are disposed three generally half cylindrical dielectric resonator elements 2, which may be made out of ceramics or other dielectric materials. The elements 2 are located in an equilateral triangular configuration with their curved faces 3 facing outwardly. Each element 2 is provided with an electrically conductive back plane 4 that electrically contacts the grounded substrate 1 by way of tabs 10 passing therethrough and is disposed generally at right angles thereto. The back planes 4 are disposed such that each is angled at 60° to its respective neighbours in a plane parallel to the grounded substrate 1.

Each element 2 has a feed comprising a slot or aperture (not shown) in the grounded substrate 1, the slot or aperture extending parallel to the back plane 4 and located under a rear edge of the element 2. Each slot or aperture is provided with a transmission line (not shown) that runs underneath the grounded substrate 1 (but is electrically isolated therefrom) and crosses underneath the slot or aperture substantially at right angles thereto. Sockets 8 are provided on a central part of the grounded substrate 1 so as to allow electrical inputs to the transmission lines.

In the foregoing respects, the LMU is similar to that of Figures 1 and 2. However, it can be seen that the LMU is inverted, and is provided with a metallic plate 110 above the grounded substrate 1. The metallic plate 110 is further provided with a layer of a radio wave absorbing material 120, and a small sensing antenna 130 is provided on an upper side of the plate 110. The sensing antenna 130 is connected to switching electronics indicated generally at 140.

From an inspection of the radiation pattern of Figure 11, it can be seen that the front-to-up ratio of the LMU is improved by a factor of 10 simply by inverting the LMU of Figures 1 and 2. The improvement factor may be increased by way of enlarging the base plate 110 and also by appropriate design factors.

The metallic base plate 110 and the radio wave absorbing material 120 help further to isolate the LMU from interfering signals emanating from above. Finally, by way of the sensing antenna 130 and the switching electronics 140, a cancellation signal can be applied to the feeds of the LMU so as to allow any interference signal to be at least partially cancelled.

Figure 13 shows two LMUs 20, 21 of embodiments of the present invention each mounted on a telecommunications mast 22 having a transmitting antenna 23. The LMUs 20, 21 are shown encased in a radome 24 and having a metallic baseplate 25. The LMU 20 is mounted in an upright configuration on the telecommunications mast 22. The LMU 21 is mounted in an inverted configuration on the telecommunications mast 22. The inverted configuration of LMU 21 is preferred, in part because the baseplate 25 helps to isolate the LMU 21 from interfering signals from the transmitting antenna 23.

The preferred features of the invention are applicable to all aspects of the invention and may be used in any possible combination.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and are not intended to (and do not) exclude other components, integers, moieties, additives or steps.

CLAIMS:

1. A dielectric antenna array comprising three dielectric resonator elements each having at least one feed for transferring energy into and out of the dielectric resonator element, wherein each element is configured to emit more radiation in a given first direction than in an opposed second direction, and wherein the elements are arranged in a triangular configuration with the first directions facing outwardly.

2. A dielectric antenna array comprising at least two dielectric resonator elements each having at least one feed for transferring energy into and out of the dielectric resonator element, wherein each element is configured to emit more radiation in a given first direction than in an opposed second direction, and wherein the elements are arranged in a configuration such that the first directions face mutually outwardly from a central point of the array.

3. An array as claimed in claim 1 or 2, wherein each element is shaped so as, in operation, to have a radiation front lobe greater in size than a radiation back lobe.

4. An array as claimed in any preceding claim, wherein each element is provided with a conductive back plane.

5. An array as claimed in any preceding claim, wherein each element is associated with a grounded substrate.

6. An array as claimed in claim 1 or any claim depending therefrom, wherein the elements are arranged in an equilateral triangular configuration such that each element serves substantially a 120° sector in azimuth.

7. An array as claimed in any preceding claim, wherein each element has a half cylindrical configuration.

8. An array as claimed in any one of claims 1 to 6, wherein each element has a quarter split cylindrical configuration.

9. An array as claimed in any preceding claim, wherein the elements are dielectric resonator antenna elements.

10. An array as claimed in any one of claims 1 to 8, wherein the elements are high dielectric antenna elements.

11. An array as claimed in claim 5 or any claim depending therefrom, wherein an additional layer of a radio wave absorbing material is provided on a side of the grounded substrate opposed to that on which the elements are disposed.

12. An array as claimed in claim 5 or any claim depending therefrom, wherein a sensing antenna adapted to receive at least a proportion of an interfering radio signal is provided on a side of the grounded substrate opposed to that on which the elements are disposed.

13. A telecommunications mast having an upper end and a lower end, with a transmitting antenna at an upper region thereof and a location monitoring unit (LMU) mounted intermediate the transmitting antenna and the lower end of the mast, the LMU being comprised as a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein the LMU is mounted with the grounded substrate positioned between the at least one dielectric resonator element and the transmitting antenna.

14. A telecommunications mast as claimed in claim 13, including a location monitoring unit comprised as an array as claimed in any one of claims 1 to 12.

15. A location monitoring unit (LMU) comprising a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein a second side of the grounded substrate opposed to the first side thereof is provided with a layer of a radio wave absorbing material.

16. A location monitoring unit (LMU) comprising a dielectric antenna having a grounded substrate, at least one dielectric resonator element disposed on or close to a first side of the grounded substrate and a feed for transferring energy into and out of the element, wherein a second side of the grounded substrate opposed to the first side thereof is provided with a sensing antenna adapted to receive at least a proportion of an interfering radio signal.

17. An LMU as claimed in claim 16, further comprising switching electronics configured to analyse an interfering signal sensed by the sensing antenna and to apply an appropriate cancellation signal to the feed of at least one element.

18. An LMU as claimed in claim 16, further comprising switching electronics configured to generate a cancellation signal with predetermined characteristics and to apply the cancellation signal to the feed of at least one element.

19. A location monitoring unit as claimed in any one of claims 15 to 18, comprised as an array as claimed in any one of claims 1 to 12.

20. A dielectric antenna array substantially as hereinbefore described with reference to or as shown in the accompanying drawings.

21. A location monitoring unit substantially as hereinbefore described with reference to or as shown in the accompanying drawings.

22. A telecommunications mast substantially as hereinbefore described with reference to or as shown in the accompanying drawings.

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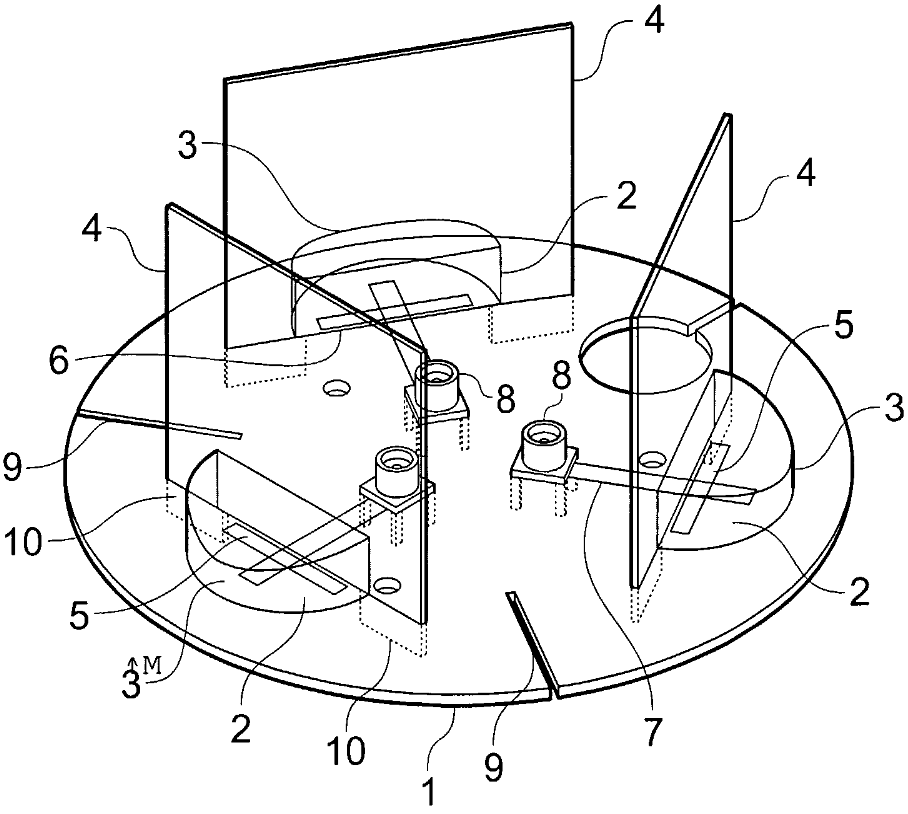

Fig. 1

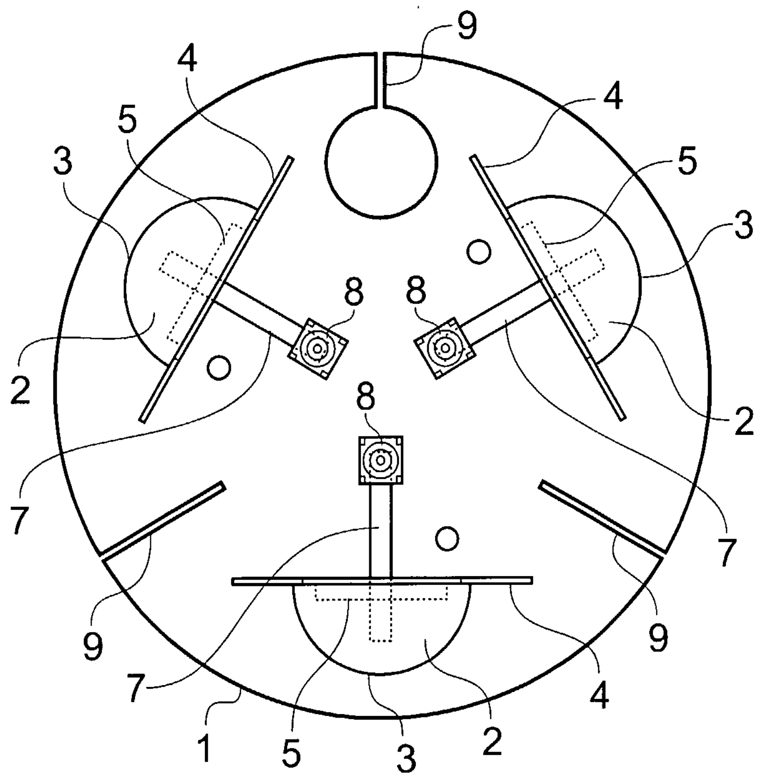

Fig. 2

LMU elevation pattern [dBi]

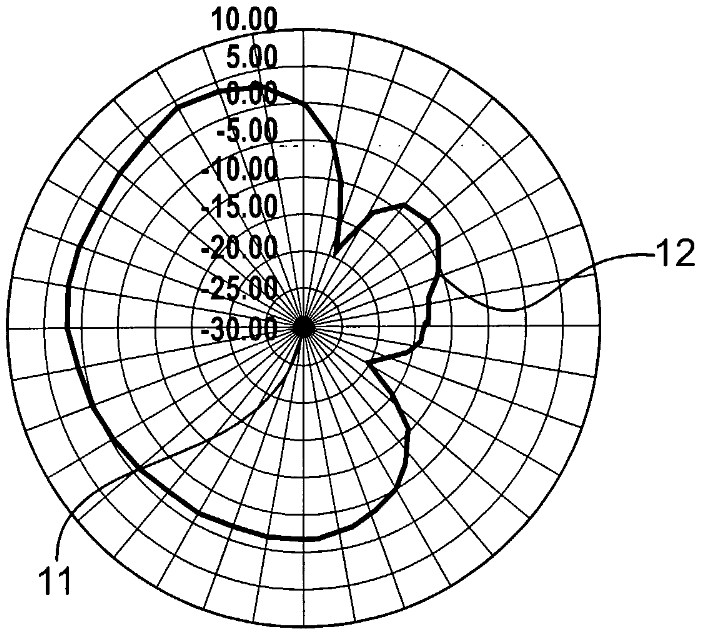

Fig. 3

LMU azimuth pattern [dBi]

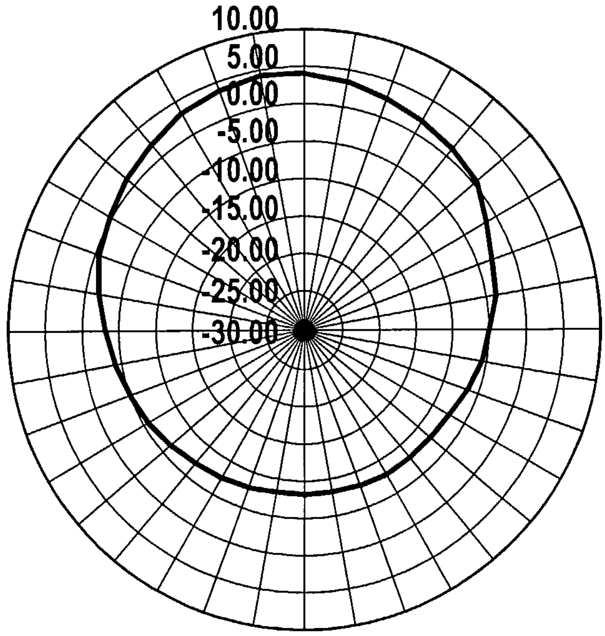

Fig. 4

LMU azimuth pattern [dBi]

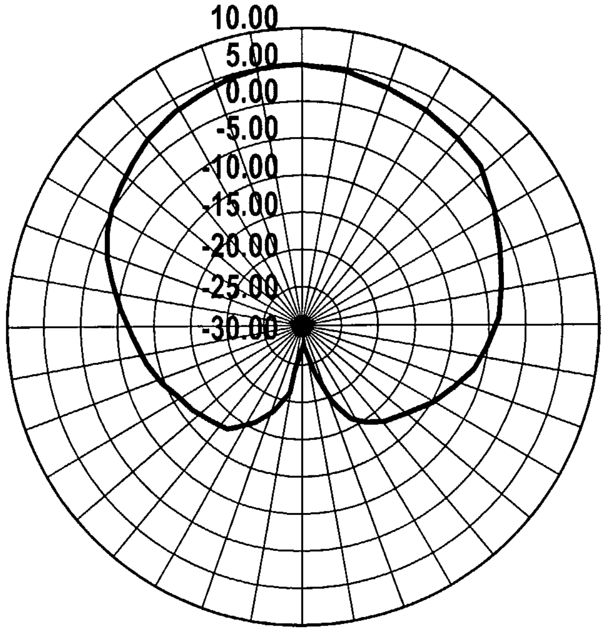

Fig. 5

LMU azimuth pattern [dBi]

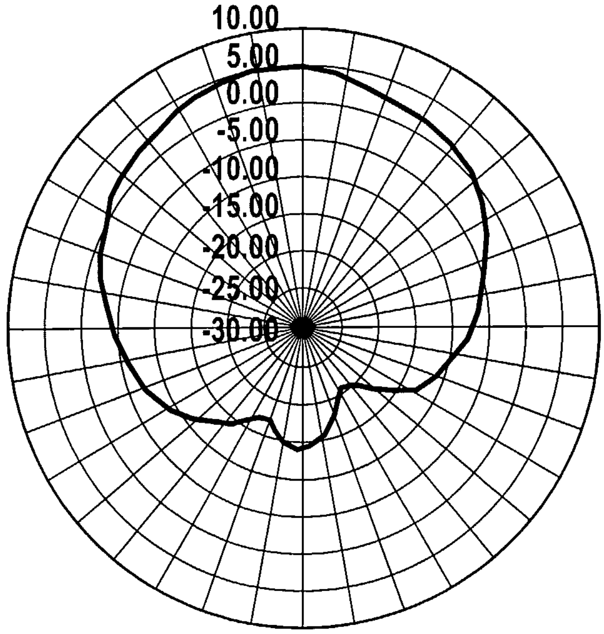

Fig. 6

Computer simulation of LMU azimuth pattern [dBi]

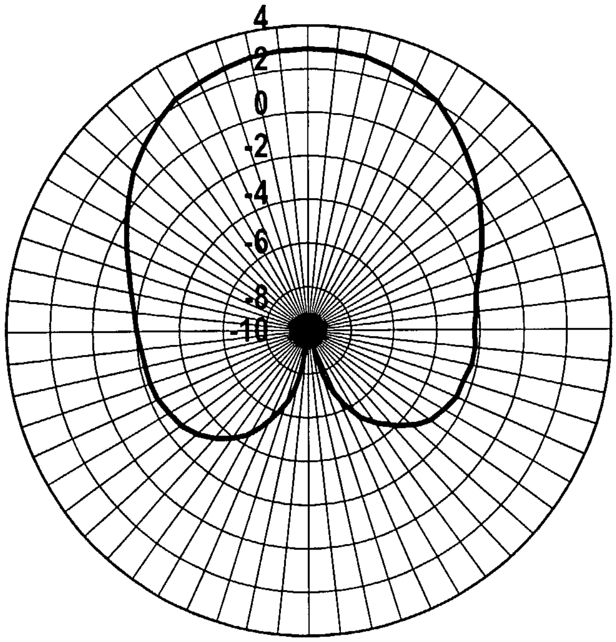

Fig. 7

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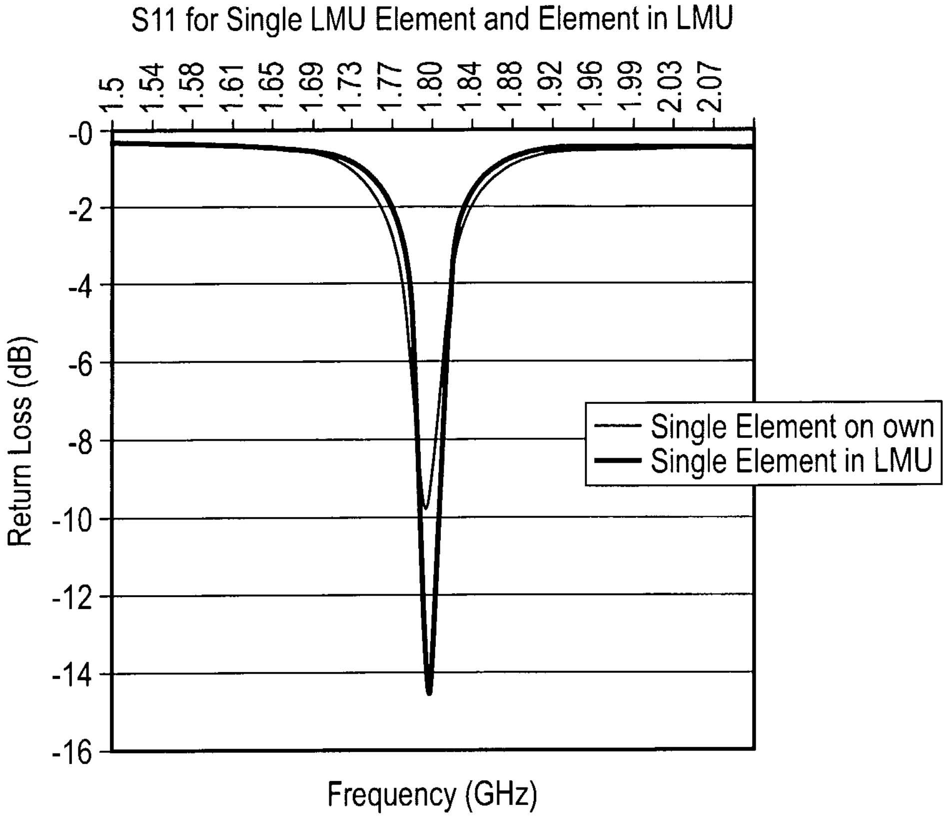
S11 for Single LMU Element and Element in LMU
1.5
1.54
1.58
1.61
1.65
1.69
1.73
1.77
1.80
1.84
1.88
1.92
1.96
1.99
2.03
2.07
-0
-2
-4
-6
-8
-10
-12
-14
-16
Return Loss (dB)
Single Element on own
Single Element in LMU
Frequency (GHz)

Fig. 8

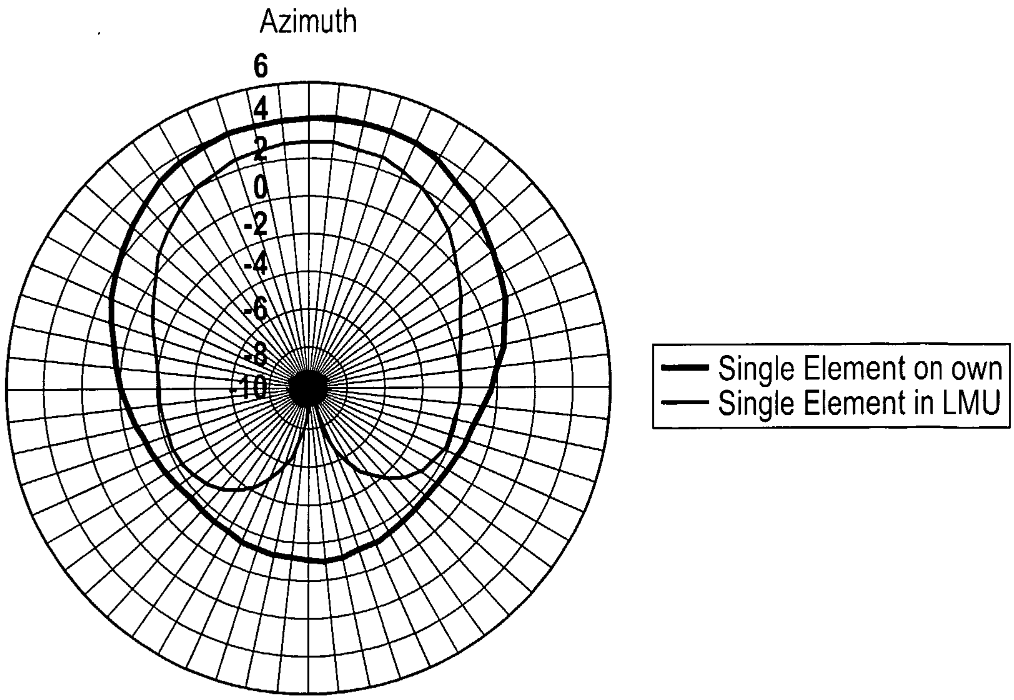
Azimuth
6
4
2
0
-2
-4
-6
-8
-10
Single Element on own
Single Element in LMU

Fig. 9

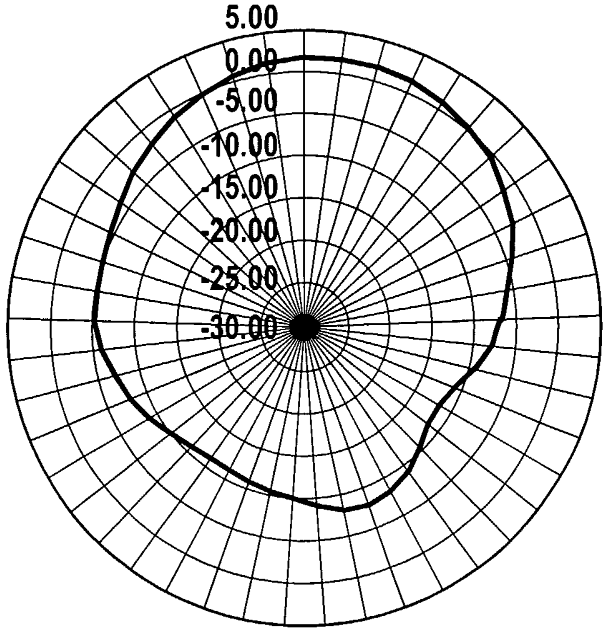
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00

Fig. 10

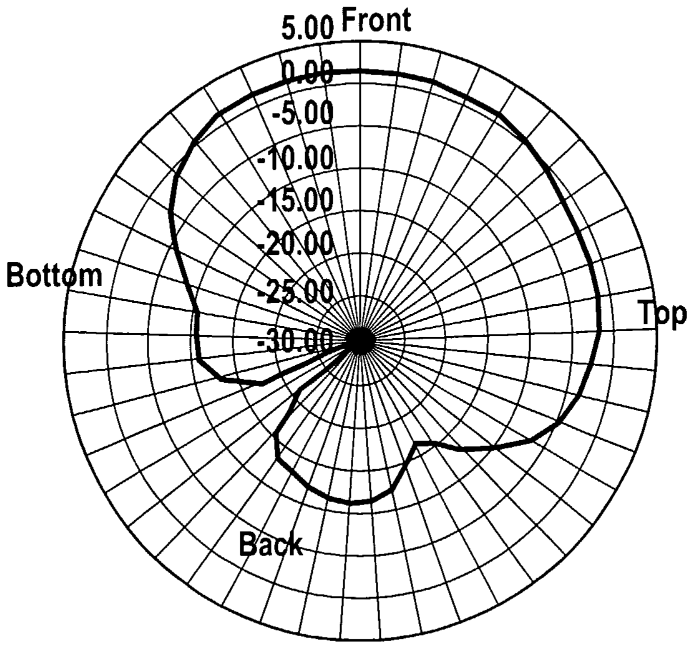
Front
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
Bottom
Top
Back

Fig. 11

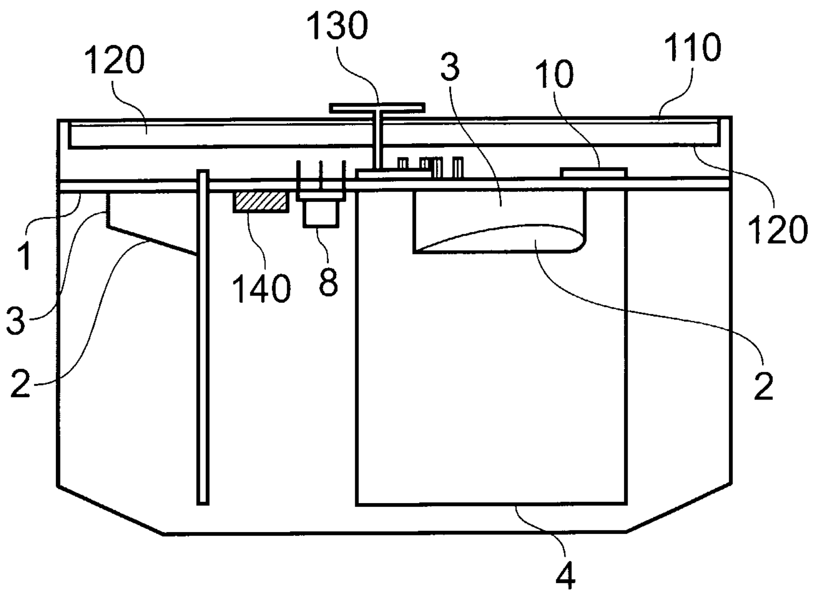

Fig. 12

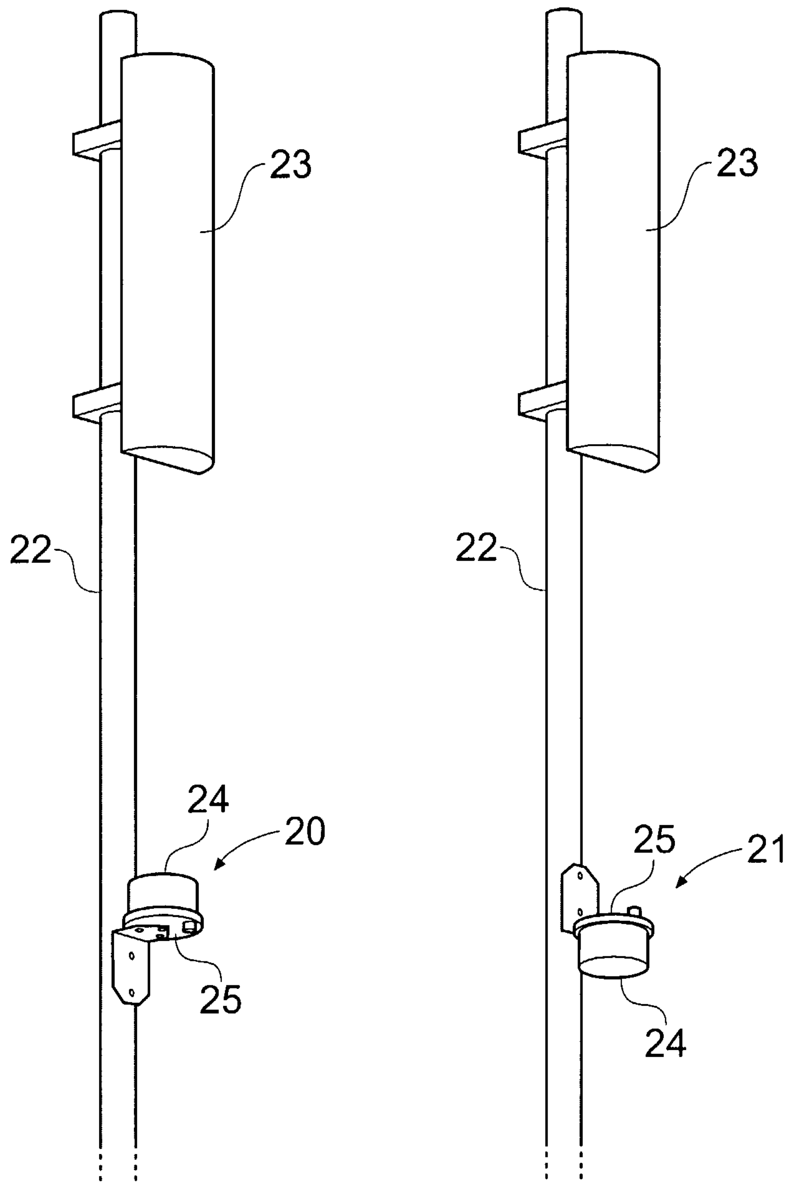

Fig. 13